DAM SAFETY ASSURANCE PROGRAM EVALUATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C – TAB II GEOTECHNICAL

DOVER DAM, OH TUSCARAWAS RIVER

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1 Purpose and Scope

This evaluation report documents project foundation characteristics and geotechnical strength parameters used for the stability reevaluation. It also describes the required subsurface investigations, geotechnical testing, and methods used to establish bedrock and soil strength parameters, drain efficiency, and preliminary seismic parameters. For general information regarding the dam and when it was constructed see paragraph 1.3 ("Existing Project Description") of the main report.

1.1 References

ASTM D1586-99	Standard Test Method for Penetration Test and Split Barrel Sampling of Soils, 10 January 1999
ASTM D 2488	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), 10 February 2000
EM 1110-1-1804	Geotechnical Investigations, 1 January 2001
EM 1110-2-1902	Slope Stability, 31 October 2003
EM 1110-2-1906	Laboratory Soils Testing, 20 August 1986
EM 1110-2-2502	Retaining and Flood Walls, 29 September 1989
EM 1110-1-2908	Rock Foundations, 30 November 1994
EM 1110-2-6050	Response Spectra and Seismic Analysis for Concrete Hydraulic Structures, 30 June 1999
ER 1110-2-1806	Earthquake Design and Evaluation for Civil Works Projects, 31 July 1995

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2 Geology

2.1 Regional Geology

Dover Dam is located in the Fairfield Township of Tuscarawas County, which is part of the Appalachian Basin.

About 2 miles upstream from the dam site, the Tuscarawas River leaves a broad, deeply filled pre-glacial valley and flows for 6 miles through a narrow steep-walled gorge of post-glacial origin. The river throughout most of the length of the gorge flows on bedrock or on a very shallow cover of alluvial sand and gravel over bedrock. Bedrock consists of nearly horizontal beds of shale, siltstone, sandstone, limestone and coal. These beds are part of the Pottsville Group of the Lower Pennsylvanian System.

The Lower Mercer limestone forms most of the foundation of the dam, with shale, sandstone, and coal over- and underlying the limestone. Below the limestone is shale into which several of the monoliths are keyed. The crystalline basement in Tuscarawas County is greater than 1,818 m (6,000’) below the top of ground.

2.2 Local Geology

At the dam site prior to construction, the river had a width of 350 feet and a low water surface elevation of 865. The valley walls rise on steep slopes from the water’s edge to an upland whose general elevation ranges from 1100 to 1200 feet. The valley consists of approximately 7 feet of alluvial sand and gravel to top of bedrock. At the dam site, the walls are of the Pennsylvanian age bedrock units of the Allegheny and Pottsville Series.

The abutments are composed primarily of shales with one 35 foot thick sandstone unit and 1 to 2 foot thick seam of coal. Bedrock is deeply weathered in the abutments but, according to the foundation reports, weathered rock was removed to ensure that all concrete monoliths were founded on sound bedrock. The groundwater surface was high in the abutments prior to construction of the dam, see paragraph 6.3 "Groundwater Conditions" for existing conditions.

The bedrock surface in the valley bottom is controlled by the upper surface of one of the limestone units. This 4-foot thick, Lower Mercer Limestone became the primary founding unit for the dam. The limestone is immediately underlain by a carbonaceous shale, ranging from 3 to 7 feet thick. Beneath this shale is a 20 to 25-foot thick, sandy siltstone which coarsens with depth into a thicker micaceous and silty sandstone unit. Due to minor local flexures, the contacts between the various bedrock units appear to form an irregular surface of an undulating nature.

Some stress-relief related fracturing and associated weathering in the dam abutments is noted in the construction foundation reports. Fracturing (slickensided joints) and some associated minor faulting is apparent in the limestone founding unit and continues thru the underlying shales and siltstones. One thrust fault of major consequence was encountered in the foundation although their were multiple minor faults too. The fault strike varies from N80°W to N75°E, dipping from 45°SW to 45°SE.

2.3 Foundation Conditions

The abutment monoliths are founded on various bedrock units. Monoliths 4 and 20 are founded on sandy shale. Monolith 3 is founded, partly on limestone and partly on sandstone. Monoliths 1, 2, 21, 22, and 23 are founded on this massive sandstone. Monolith 5 was founded on the Lower Mercer Limestone unit. All of the abutment monoliths are embedded into bedrock excavations with confinements both upstream and downstream by weathered rock which was deemed during design, suitable to provide the necessary sliding stability.

All of the spillway monoliths (Monoliths 7 through 15) along with non-overflow monoliths 16 through 19 are founded on top of the Lower Mercer Limestone, see Exhibit II-8 "Rock Profiles and Sections." This approximately four-foot thick limestone is continuous across the valley bottom and is underlain by a less competent carbonaceous shale of similar thickness. The logs from the 1982-83 exploration program describe moderate to severely broken zones in the carbonaceous shale. The limestone serves as the primary founding unit for the monoliths including the associated stilling basin monoliths and retaining walls. Founding elevations vary from 847 to 855. At the upstream heel of the dam a 20 foot deep rebar reinforced key was formed through the carbonaceous shale and into an underlying sandy-siltstone. The reinforced key was necessary to provide the required factor of safety against sliding failure.

After the limestone was exposed, the above mentioned fault was observed trending approximately east to west across Monoliths 14, 14A and 15, see Exhibit II-8 "Mapping of Faults and Joints." The fault extends through the limestone and into the underlying shales. It is further described in the Addenda to the Analysis of Design, Dover Dam (1939): "Two types of displacement have occurred. The limestone capping the north side of the fault was pushed over that on the south side forming a "thrust" fault. On the other hand, the shale on the north side moved downward in relation to the shale on the south side, resulting in a typical "reverse" fault. Both movements are due to compression but a thrust fault dips less than 45^{o} and a reverse dips greater than 45^{o}. This faulting resulted in a 2 foot thick opening between the limestone and shale and severe broken conditions in the shale along the fault." Because of this faulting the foundations for Monoliths 14, 14A and 15 were lowered to the sandy-siltstone at the elevation of the originally planned key. Extensive grouting was performed under the foundation along both sides of the fault and in Monoliths 12 and 13 to fill the opening between the limestone and the siltstone.

A fault striking N-S and dipping about 70° E was seen in the limestone in monoliths 13B and 13C. It was a normal fault with about 2 ½ feet of displacement. It cut a second fault that was striking E-W. It showed about 3 feet of offset on an overthrust.

Smaller faults, striking N-E to N25°E, all nearly vertical, with displacements of 1 to 2 feet were also reported to the north of the major fault. All cut the limestone and shale, but were not readily traceable in the underlying sandstone except in a grout hole in monolith 11. The sandstone from elevation 800' MSL to 810' MSL was "shattered" and severely broken. This may be a fault, but it was only intercepted by one boring and never excavated, so no more is known about it.

A number of other minor faults were encountered in the foundation of the dam and stilling basin monoliths. The faults and joints were mapped and reported in each monolith foundation report, these were compiled and are shown in Exhibit No. II-8. These faults and major joints and fractures in the foundation were treated with special grout lines placed in the discontinuity.

At the upstream face of Spillway Monoliths 7 through 15 and Non-Overflow Monoliths 16 through 19, a cutoff trench was excavated 20 feet deep and 10.5 feet wide at the bottom with a downstream face sloped 2 vertical on 1 horizontal. The trench extended to elevation 830 for Monoliths 7 through 12 and to elevation 835 for Monoliths 13 through 19. Grouting was performed on the upstream and downstream sides of the cutoff trench prior to beginning rock excavation. Final grouting was performed through 3-1/2-inch diameter preformed vertical holes on 5-foot centers at the base of the cutoff trench. Grouting was performed from the top of the first pour.
The grout holes were drilled 30 feet into rock and were grouted with 30 psi pressure in the top 15 feet and 80 psi in the bottom 15 feet of grout hole.

The upper surface of the founding limestone member slopes more steeply at the downstream limit of the stilling basin thus less erosion resistant shales form the bedrock surface at that location. In order to prevent scouring of the channel bottom downstream from the end of the apron, a 20-foot strip of derrick stone was placed against the apron end sill over about one-half the width of the stilling basin. A 15-foot stepped slab of concrete was placed against the downstream face of the apron and doweled into the limestone and the concrete over the remaining (north) one-half of the basin.

2.4 **Seismicity**

ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects (1995), Appendix C, Uniform Building Code Zone Map shows Dover Dam in seismic zone 1.

In May of 1999 AE Contractors Fuller, Mossbarger Scott & May, (FMSM) submitted the "Seismic Analysis Report for the Muskingum River Basin". The objective of this study was to evaluate and develop seismic ground motions for use as the basis for future studies in the Muskingum River Basin. As the need for analyses, designs and/or remediation projects arise at each of the 16 dams or their appurtenances, this study will serve as the basis for the development of site specific ground motions. This report is intended to partially satisfy requirements in ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects (1995) and ER 1110-2-1155 Dam Safety Assurance (1997) for a Phase 1 seismic study. Other references such as Engineering Circular 1110-2-6050 and "Fundamentals of Earthquake Resistant Construction" by Krinitzsky, Gould and Edinger, Published by Wiley, 1993 were utilized as guides in completion of the study.

The recommended Operation Basis Earthquake (OBE) consists of a magnitude 5.2 m_b event having an epicentral distance of 15 km and a focal depth of 5 km. The resulting peak horizontal acceleration (PHA), peak horizontal velocity (PHV) and duration are 98 cm/sec^2, 6.1 cm/sec and 3.9 seconds, respectively. The recommended Maximum Credible Earthquake (MCE) consist of a magnitude 5.5 m_b event having an epicentral distance of 20 km and a focal depth of 5 to 10 km. The resulting PHA, PHV and duration are 147 cm/sec^2, 11.2 cm/sec and 6.8 seconds, respectively. The recommended acceleration values for the OBE and MCE are believed to roughly correspond to the mean plus one standard deviation hazard for return periods of 144 and 500 years, respectively. Alternatively, the OBE and MCE correspond to the 400 and 3000 year return interval events respectively, when compared to the mean hazard. The equal hazard spectra indicate the highest spectral acceleration is realized at frequencies ranging from 5 to 20 Hz which is expected for this region of the United States.

The FMSM 1999 report concludes that for most structures, the motions supplied with the report could be used without alteration. However, other structures, such as Dover Dam, may be sensitive to a narrow range of frequencies not investigated because of the general nature of the study. Consequently, it is recommended that a future study be done that reviews the motions supplied in the FMSM 1999 report and alters them, as necessary, for Dover Dam's site specific conditions.

3 Stability Re-analysis

Concerns over project stability have been documented in past periodic inspection reports. These concerns, due primarily to changes in analysis methodology and foundation uncertainties, have resulted in recommendations for reanalysis, and programs of subsurface investigation.

Typical non-overflow and spillway monoliths were reanalyzed for structural stability after the second periodic inspection. The analyses are documented in Appendix V of that inspection report, transmitted 17 June 1977. For the 1977 reanalysis, parameters such as compressive strength, cohesion, and shear friction angle for certain foundation lithologies were assumed, based on engineering judgment. Strengths for other members were derived as weighted averages from the test data used for the original design. (See Appendix III of Periodic Inspection Report No. 1, for the original test results).

For the 1977 reanalysis, the stability was evaluated using full uplift over 100% of the base area. The rock properties used in the original design were adopted. These strengths discounted cohesion on the bedding planes. Resistance to sliding was dependent upon passive resistance due to embedment of the monoliths into rock. The stability was analyzed using the "Sliding Resistance Method" which looks at the ratio of horizontal forces to vertical forces. Results of the analyses indicated that all monoliths appeared to be safe against overturning, sliding, and bearing failure except Monoliths 7 through 9. The factor of safety against sliding for Monoliths 7 through 9 was found to be 0.75. The report went on to recommend a program of foundation exploration and further analyses.

The Endorsements to the 2nd Periodic Inspection Report concurred with the above recommendation (refer to 1st Endorsement, subject "Dover Dam, Ohio, Periodic Inspection Report No. 2," dated 4 October 1977; and OCE letter, subject same, dated 2 November 1977). Ohio River Division directed the District to submit a completed plan, schedule and cost estimate for the foundation exploration program. The drilling, completed in 1983, is discussed in the next section.

4 Geological Investigations to Date

The site geology was investigated during the design and construction of the dam by drilling forty-two core borings located along seven ranges across the valley bottom. These ranges are located from 600 feet upstream of the dam axis to 600 feet downstream. Four 6-inch diameter holes were drilled for test samples. In addition to the core borings, four test pits were dug to depths ranging from 25 to 61 feet. Two investigative programs have been carried out since the third periodic inspection.

4.1 1982-83 Investigations

The first program consisted of 15 NX borings, 3 vertical and 12 angled drilled from inside the operations gallery. The borings were logged by a Huntington District Geologist and the strike and dip of the prominent joints were calculated from the angled borings (see Exhibit II-10). Core loss was 5.6% or 17.7 feet for 316.5 feet of drilling. A boring plan and logs are included in Exhibits II-1 and II-4 respectively.

4.2 2004 Investigations

4.2.1 Rock Coring

The drilling program consisted of 14, 4-inch core borings located on each abutment. See Exhibit II-1 and II-4 for the location and logs of these borings. The exploration program's main purpose was to characterize the foundation conditions in the abutments which had not been considered in the earlier drilling program. Another facet of this drilling program was to obtain and test materials lithologically similar to those in the valley bottom, and attempt to interpolate rock strengths across the valley between the abutments. Core recovery, was higher than the earlier exploration program with only 0.3% or 2.8 feet lost in 839.8 feet of drilling. The core barrel used was a 5ft Hoffman double tube with a split inner barrel. The core was sealed in plastic to maintain moisture content, and placed in core boxes padded with sawdust to keep the core in good condition during shipping and handling and prior to test sample selection. The borings were re-logged by Huntington District geologists.

4.2.2 Overburden Drilling, Sampling and Testing

Fifteen (15) borings (C-04-1 to C-04-14 & C-04-5A) were drilled in 2004, primarily to obtain rock core samples for testing. Overburden was sampled in each boring using the Standard Penetration Test (SPT) method (2-inch slit spoon), in accordance with ASTM D 1586, with blow counts taken continuously. No undisturbed sampling was performed. Borings were drilled at the upstream and downstream sides of both abutments. Four (4) borings were drilled downstream of the dam in/near the right abutment, and two (2) were drilled upstream of the dam near the right abutment.

Of the four borings drilled in the right downstream area, one boring (C-04-5) was abandoned at a depth of 35.5 feet due to the presence of petroleum odors. This was encountered in a zone of weathered sandstone and shale. Drillers placed the auger cuttings into two (2) fifty-five (55) gallon drums, as noted on the field logs. A "slight petroleum-like odor" was noted on the drilling field log in a zone of silty clay (depth: 25.5 to 31 feet) near the ambient groundwater level of this boring. As a result, boring C-04-5A was drilled approximately 50-feet upstream of C-04-5. Similar to the right abutment, two (2) borings were drilled upstream of the dam near the left abutment, and three (3) borings were drilled just downstream of the dam near the left abutment. No borings were drilled in the river. Locations and graphic logs of these borings are shown in Exhibits II-1 and II-4, respectively.

Jar samples from split spoons were collected and were visually described using the Unified Soil Classification System (USCS), in accordance with ASTM D 2488. Natural moisture contents were also determined on most (173 out of 176) of the overburden samples. Sieve analyses were completed on approximately 15% of all jar samples, and representative samples of the fine-grained soil samples were tested to determine Atterberg Limits. No testing, beyond standard index testing to classify the soil types, was performed. These test results are included on the graphic logs in Exhibit II-4.

5 Rock Testing

For the 2005 rock testing program, all samples were taken from the 2004 drilling program and sample selections were done by Huntington District personnel. Sample preparation and testing was carried out by FMSM Engineers, Inc. of Lexington, Kentucky, an Army Engineer Research and Development Center (ERDC) validated lab, in accordance with the applicable provisions of the "Rock Testing Handbook," WES Geotechnical Laboratory Publication, March 1990.

The main goal of the 2005 testing program was to provide shear strengths and bearing capacities for the reanalysis of the dam.

TABLE II-1 Summary of Dover Dam Rock Strengths

	Cross Bed Shear Intact Peak (ϕ) (c) psi	Shear Parallel to Bedding Natural Fracture Peak (ϕ) (c) psi	Basic phi angle Smooth Sawn Surface (ϕ) (c) psi	Bedrock Dam Interface Grout on Rock Peak (ϕ) (c) psi	AllowableBearing psi	E_{t50} Elastic Modulus (x10^6)	Unit Weight
Limestone	65 150 psi***	39 7 psi	29 0 psi	50 33 psi****	2191	24.740	168.5 pcf
Upper Sandstone	64 88 psi***	28 3 psi	26 0 psi	50 70 psi****	522	2.050	148 pcf
Sandy Siltstone	46 20 psi***	26 2 psi	21 0 psi	50 60 psi****	829	2.970	159.7 pcf
Siltstone	31 15 psi***	25 1.5 psi	14 0 psi	31 60 psi****	873	2.750	165.8 pcf
Shale	29 5 psi***	19 .5 psi	12.5 0 psi	30 50 psi****	300	1.750	161.5 pcf
Fault/Slickensided Joint*	19* 0 psi						
Concrete Key Lift Joint**		38 Controlled by Rebar**					

Shear Parallel to Bedding when used with the key should be reduced by 50% due to strain incompatibility with the rebar
*The cross bed shear strength assigned to the (Fault / Slickensided Joint) is the average of the basic phi angle for all of the materials except the Upper Sandstone. The Upper Sandstone was excluded because it is not a component in the passive wedge of the 3 monoliths analyzed.
**The cohesion value used in the concrete key is assigned by structural section and is not published here.
***The cross bed shear cohesion was taken directly from the intact peak lower bound plot except cohesion was then reduced by 50 percent to account for scaling effects.
****The cohesion was taken directly from the lower bound plot of the grout on rock peak except cohesion was reduced by 66 percent to represent portions in the monolith where the contact is not bonded.

5.1 Sliding Shear Strength

Sliding shear strength is used to represent the shear strength of the rock where the direction of the shear is parallel to the discontinuity. The majority of the discontinuities in the foundation of Dover Dam are oriented nearly horizontal.

A total of forty-two (42) direct shear tests were run on core samples which represent natural fractures. Normal loads varied from 40 to 120 psi. Similar tests were also run on smooth-sawn samples to determine the basic phi angle of the materials (additional discussion on smooth-sawn sample testing in section below). The peak strengths of these natural fracture tests were plotted, and were taken into consideration along with the smooth-sawn tests to effectively establish an upper and lower bound of the appropriate values for sliding strength along open natural fractures in the foundation. The upper and lower bounds, the chosen natural fracture sliding strengths, and cohesion of the rock mass were chosen as follows:

- **Upper Bound**. The linear regression plot of the peak strengths was assumed to represent an upper bound of this sliding strength because it includes the resistance of both the basic phi angle of the material, and the additional resisting influence of the "second-order" irregularities within the sample itself. The second-order irregularities are normally at a higher angle than the "first-order" irregularities (or *"i"* angle) within the overall rock mass; therefore, the angle of the linear regression for these natural fracture peak strengths can be used as an upper limit of the natural fracture sliding strength envelope.
- **Lower Bound**. The plot of the smooth-sawn surfaces, without the influence of the first- or second-order irregularities, is assumed to represent the lower bound of the natural fracture sliding strengths. Post-peak (residual) natural fracture plots are not presented in this report since smooth-sawn surface tests were available.
- **Rock Mass Sliding Strength**. The rock mass shear strength along natural fractures is represented by the basic phi angle of the material plus the additional strengthening influence of "first-order" irregularities within the rock mass. The first-order *"i"* angle was chosen based on engineering judgment. As expected, the rock mass sliding strength line plotted between the upper and lower bounds described above. (A selection of plots and the associated shear strength data are included in Exhibit II-6 .)

Cohesion. The linear regression plots of the natural fracture peak shear strengths are plotting at or near the xy intercept. The cohesion values used for design are based on engineering judgment, taking into account the apparent cohesion intercept at zero normal load and the characteristics of the natural fracture.

5.2 Cross Bed Shear Strength

Cross bed shear strength is used to represent the shear strength of the rock where the direction of the shear is not parallel to the bedding but crosses through the bedding. In the sliding stability analysis the cross bed shear strength of the rock is used to characterize the base of the passive wedge except where the foundation reports or exploration indicate faults or slickensided joints (see Photo II-1) are present along the base of the passive wedge, in these cases the base of the passive wedge is better characterized by the basic phi angle obtained from the smooth sawn surface shear strength.

A total of forty-five (45) direct shear tests were run on intact foundation rock at normal loads varying from 40 to120 psi. Subsequent to failure at peak strength the tests were continued to obtain sliding resistance. The lower bound plot of the peak strength was used to characterize cross bed shear. The phi angle and cohesion were taken directly from the lower bound plot except cohesion was then reduced by 50 percent to account for scaling effects. The intact rock strengths selection was based on engineering judgment and in accordance with Corps guidance (EM 1110-1-2908).

5.3 Smooth Sawn Surface Shear Strength

Smooth sawn surface shear strength is used to represent a slickensided plane and to check the phi angle of the natural fracture (minus the first-order i angle).

A total of thirty (30) direct shear tests were run on sawn surfaces of foundation rock at normal loads varying from 40 to 120 psi. Typically the phi angle can be calculated from the plot of the peak shear stress, but the lab was unable to discern any peak shear stresses for the limestone or the upper sandstone, however post peak shear stresses were obtained for all rock types. To be consistent the post peak shear stresses for all of the rock types were used to calculate the phi angle, but instead of plotting a lower bound the phi angle is closer to the linear regression and any apparent cohesion plotted is ignored.

Photo II-1 *Scanned photo from monolith 7 foundation report. The photo was taken from monolith 7 looking down stream at monolith 7A. Notice the bar that is resting on what is described as a fault. The fault or slickensided joint is dipping upstream.*

5.4 Grout on Rock Shear Strength

Grout on rock shear strength is used to represent the interface of the monolith and the bedrock.

A total of forty-five (45) direct shear tests were run on sawn foundation rock surfaces bonded to grout at normal loads varying from 40 to 120 psi. The lower bound plot of the peak strength was used to characterize the contact of the monolith and the bedrock. The Phi angle and cohesion were taken directly from the lower bound plot except cohesion was reduced by 66 percent to represent portions in the monolith where the contact is not bonded. Of the three (3) vertical 1982-1983 gallery borings one (1) describes the concrete to rock interface as intact with the remainder being open. The angled borings do not describe the condition of the concrete to rock interface.

5.5 Elastic Modulus

A total of thirty-eight (38) unconfined compression tests were performed on abutment bedrock samples. Axial and diametrical deformations were measured to allow derivation of elastic constants. The elastic modulus was derived from the slope of a line constructed tangent to the stress-stain curve at 50 percent of the peak stress.

5.6 Allowable Bearing Capacity

The allowable bearing capacity was calculated using Goodman's (Introduction to Rock Mechanics, page 311, Eq. 9.8) for ultimate bearing capacity and applying a factor of safety of 5. Goodman's equation uses the unconfined compressive strength, vertical joint spacing, monolith width, and intact rock Phi angle to calculate the ultimate bearing capacity. Goodman's equation was chosen over those given in EM 1110-1-2908 because it was more consistent, see exhibit II-6 for a comparison.

5.7 Failure Plane Selection

Multiple failure scenarios are shown in cross section with each monolith (see Exhibit No. 2) based on the stratification, location and orientation, frequency and distribution of discontinuities of the foundation material, and the configuration of the base. Each segment of the failure path is assigned a strength based on the material type, its condition and orientation. The angle of the base of the passive wedge was defined by the classical Coulomb passive failure plane equation ($45-\theta/2$). Monoliths 5 and 7 show faults in the area of the passive wedge and are characterized using a smooth sawn surface shear strength. Monolith 17 shows no faulting in the passive wedge and therefore uses cross bed shear strength. The multiple failure options were then analyzed by the structural engineer, who selected the most critical potential plane of failure.

5.8 Unit Weight

The unit weight of each rock type was calculated from material leftover from the unconfined compressive tests. The specimens were prepared and tested in accordance with guidelines established in RTH 109-93. The test data from each rock type was averaged and the average is published in TABLE II-1.

6 Soil Characterization

Overburden characteristics are needed for soils found around the abutments and immediately upstream and downstream of dam monoliths. Soils in and around the abutments have been categorized as in situ soils, compacted backfill, rolled embankment, rock fill, and upstream north abutment slide backfill. Soils placed immediately upstream and downstream of dam monoliths have been termed compacted backfill. The aforementioned categorizations are consistent with naming conventions shown on project as-built drawings.

Overburden characteristics are needed for two design purposes for this project. First, the soils along each downstream abutment offer resistance to sliding of monoliths 1-6 and 16-23. Therefore, engineering properties of these soils are needed to determine the amount of resistance they provide. Secondly, fills placed upstream of abutment monoliths add both vertical and horizontal stresses on the upstream face of abutment monoliths. Engineering properties have been selected to quantify these stresses for sliding stability analyses. The following discussion explains the selection of engineering properties of these materials.

Engineering properties for all known soils at this project have been selected using 2004 drilling and testing data, published correlations, and engineering judgment based on experience. At-rest earth pressure coefficients for use in structural analyses have been selected based on empirical relationships to shear strength parameters for granular soils, and published correlations for cohesive soils as shown in Table II-2. Tables II-3 and II-4 were utilized for correlating soil properties at the project based on SPT blow counts (N-values) obtained during drilling. Table II-3 below was used for cohesive soils (>50% passing the #200 sieve), while Table II-4 on the following page was used for granular (cohesionless) soils.

Table II-2 – *Typical Coefficients of Lateral Earth Pressure At-Rest (from Clough and Duncan, 1991)*

		Coefficient of Lateral Earth Pressure At-Rest (K_o)			
Soil Type	***Φ_f (deg)***	***OCR = 1***	***OCR = 2***	***OCR = 5***	***OCR = 10***
Loose Sand	33.5	0.45	0.65	1.10	1.50
Medium Sand	36.5	0.40	0.60	1.05	1.55
Dense Sand	40.5	0.35	0.55	1.00	1.50
Silt	29.5	0.50	0.70	1.10	1.60
Lean Clay, CL	23.5	0.60	0.80	1.20	1.65
Highly Plastic Clay, CH	20.5	0.65	0.80	1.10	1.40

Table II-3 – *Approximate values of undrained shear strength for cohesive soils based on SPT blow count N-values (from Terzaghi and Peck, 1967)*

Soil Consistency	**SPT N**	**S_u (psf)**
Very Soft	< 2	< 250
Soft	2 - 4	250 - 500

Medium	4 - 8	500 - 1000
Stiff	8 - 15	1000 - 2000
Very Stiff	15 - 30	2000 - 4000
Hard	> 30	> 4000

***Table II-4** – Empirical values for Φ, D_r, and unit weight of granular soils based on the standard penetration number with correction for depth and for fine saturated sands (from Bowles, 1968)*

Description	Very loose	Loose	Medium	Dense	Very dense	
Relative density D_r	0	0.15	0.35	0.65	0.85	1.00
Standard penetration no. N		4	10	30	50	
Approx. angle of internal friction ϕ°†	25°–30°	27–32°	30–35°	35–40°	38–43°	
Approx. range of moist unit weight, (γ) pcf	70–100‡	90–115	110–130	110–140	130–150	

† After Meyerhof [9]. $\phi = 25 + 0.15D_r$ with more than 5 percent fines and $\phi = 30 + 0.15D_r$ with less than 5 percent fines. Use larger values for granular material with 5 percent or less fine sand and silt.

‡ It should be noted that excavated material or material dumped from a truck will weigh 70 to 90 pcf. Material must be quite dense and hard to weigh much over 130 pcf. Values of 105 to 115 pcf for nonsaturated soils are common.

6.1 General

Extents of soils have been determined and correlated from as-built project drawings and construction notes contained in Dover Dam Periodic Inspection Report No. 1, as well as 2004 LRH boring data. Project As-Built drawings show that the original ground surface on the right abutment sloped riverward at about 1V:2H from old State Road No. 8 (Sta. 1+50) to the former Ohio Canal (Sta. 3+00) at about El. 879, and continued at a gentle slope to the river. As-built drawings also show a depth of approximately 30 feet to rock below these cohesive, in situ soils. Original dam construction (started 1935) included placement of fill, termed rolled embankment in project as-built drawings, over these in situ soils to current elevations. Rolled embankment was placed to a 1V:1.5H slope from the top of the right abutment (El. 933.7), to the middle of Monolith 6 at El. 885. Two 9.5 foot wide berms interrupt the slope at El. 918.3 and El. 902. Therefore, about 18-20 feet of rolled embankment fill was placed in the right abutment area.

Due to a landslide in the upstream right abutment during construction, in situ soils were removed to rock and replaced with rolled embankment. Twenty to thirty feet of rock fill consisting of sandstone from an upstream quarry was placed over the rolled embankment to current elevations. The original ground surface of the left abutment sloped riverward at about 1V:3H. Approximately 20 feet of in situ soil was removed and graded to 1:2 and 1:3 slopes with benches at El. 902 and El. 885. Immediately downstream and upstream of the dam monoliths starting at the top of rock and monolith contact point and rising at a

1:1 slope to the existing ground, is of compacted backfill. An exception to this is uncompacted backfill on the downstream side of monoliths 20 and 21.

Based on as-built drawings and confirmed by 2004 boring data, the soil column along the downstream right abutment at Monolith 5 consists of in situ soils from the top of rock approximate El. 867 to El. 883, and rolled embankment from El. 883 to El. 902. Upstream of Monolith 5 consists of US north abutment slide backfill from top of rock to El. 883, rolled embankment from El. 883 to El. 894, and rock fill from El. 894 to El. 915. Compacted backfill is located immediately upstream and downstream of the dam at the right abutment from the top of rock to the existing ground surface. Along the left abutment at Monolith 17, the soil column is believed to consist of in situ soils from top of rock to the ground surface (El. 886). Borings drilled in 2004 in the left abutment downstream of the dam (C-04-8, 9, and 11) were located in areas of uncompacted backfill. See Exhibit II-5 for sections showing soil stratigraphies at Monoliths 5 and 17. Engineering properties for all of these materials were needed for stability analyses and for evaluating construction alternatives. Table II-5 below lists selected engineering properties for all these soils.

Table II-5 – SOIL PROPERTIES

Material	K_o	Short-term Condition				Long-term Condition			
		γ_{sat} (pcf)	γ_{mst} (pcf)	Φ (deg)	S_u (psf)	γ_{sat} (pcf)	γ_{mst} (pcf)	Φ (deg)	S_u (psf)
Rock Fill	0.45	130	120	35	0	130	120	35	0
*Compacted Backfill	0.45	125	120	35	0	125	120	35	0
Rolled Embankment	0.45	125	120	33	0	125	120	33	0
In situ soils	0.70	128	125	0	1500	128	125	31	0
+US North Abut. Slide Backfill	0.55	120	110	28	0	120	110	28	0
Uncompacted Backfill	0.60	125	120	0	800	125	120	30	0

** Compacted backfill is located adjacent to upstream and downstream sides of monoliths #5 & #17 and behind the right training and retaining walls.*
+ See Periodic Inspection Report No. 1, Appendix IV, pg. 13, Section 8. Construction Notes.

6.2 **Existing Soils**

6.2.1 In Situ Soils

Borings C-04-5, C-04-5A, and C-04-6, located on the right abutment, show that soil samples taken below El. 883 generally contain 60-75% clays and silts, 10-25% sand, and

5-15% gravel, by weight. In situ soils found along the left abutment in boring C-04-10 generally contain 50-60% silt and clay, 15-20% sand, and 20-25% gravel, so they are generally classified as sandy clays with gravel.

These soils generally exhibit medium plasticity with liquid limits of 35-40% and plasticity indices of 21-23 (See Exhibit II-4 for Atterberg Limits test data). Penetration resistances observed during drilling are indicative of a stiff consistency (N-values of 8-20 blows/foot). N-values within the anticipated in situ soil layer in borings C-04-5A, 5, 6, and 10 averaged 11 to 16 blows/foot.

As noted previously, no undisturbed sampling was performed. Published correlations were reviewed to obtain approximations of the at-rest earth pressure coefficient and undrained shear strength parameter. These correlations are shown in Tables II-2 and II-3 and were used to select the parameters shown in Table II-5. Engineering judgment and past testing results for similar soils from other District projects was used to determine the drained shear strength parameter.

Using Table II-2, in situ soil was assigned an at-rest earth pressure coefficient (K_o) of 0.70. This is considered reasonable because although consolidation testing was not performed it is estimated that these soils, which fall under the lean clay (CL) category in the table, are overconsolidated. An overconsolidated soil is defined as a soil whose present effective overburden pressure is less than that which the soil experienced in the past. Since overlying soils were removed from the present in situ soils of the left abutment during construction, these soils are considered overconsolidated. Due to a landslide during construction, the in situ soils upstream of the right abutment were removed and backfilled with granular soils. The downstream right abutment in situ soils were covered with about 20 feet of granular rolled embankment during construction. Project in situ soils are estimated to fall between an overconsolidation ratio (OCR) of 1 and 2 in Table II-2. Using Table II-2, a lean clay with an OCR midway between 1 and 2 would have a value of K_o=0.70.

As noted previously, N-values for in situ soils averaged 11 to 16 blows/foot.; 11 blows/foot is roughly in the middle of the N-value range of stiff clay in Table II-3. As a result, in situ soil was assigned an undrained shear strength value of 1500 psf, which is midpoint in the range of 1000 to 2000 psf as shown in Table II-3 for stiff clay.

6.2.2 Compacted Backfill

Compacted backfill was placed between excavated soil and the dam monoliths on both their upstream and downstream sides, with the exception of the downstream side of monoliths 20 and 21. Compacted backfill was also placed between excavated rock and structural concrete for the right retaining (upstream) and training (downstream) walls.

As previously noted, no project specifications are available. As a result, little is known of the composition and requirements for compacted backfill. The 2004 borings (C-04-5A and C-04-6) show that in areas of compacted backfill, the soils typically contain approximately 15% fine-grained materials (% passing the #200 sieve) with wide variations in sand and gravel proportions. The natural moisture contents of these soils ranged from 5 to 12%. Based on 2004 boring data, compacted backfill is characterized by about 15% fines, whereas in situ soils contain about 50-70% of fines. Compacted backfill is generally classified as silty sands and gravels.

Areas of compacted backfill in borings C-04-5A and C-04-6, averaged N-values of 20-25 blows/foot, correlating to a medium dense granular soil in Table II-4. By using Table II-4, compacted backfill with average N-value of 20 blows/foot was assigned an internal angle of friction (Φ) of 35° and moist unit weight of 120 pcf, which correspond to Φ and unit weight values midway between N-values of 10 and 30 blows/foot. Effective shear strength parameters and unit weights for compacted backfill and rolled embankment were estimated to be relatively similar based on blow counts (N-values) and gradations. Table II-5 lists all selected parameters for compacted backfill soils.

6.2.3 Rolled Embankment

Rolled embankment was placed over in situ soils in the downstream right abutment and upstream left abutment, as well as over the slide backfill in the upstream right (north) abutment. The exact composition and compaction placement procedures for rolled embankment are unknown. 2004 borings show that areas of rolled embankment soils typically contain approximately 15% of fine grained materials and varying amounts of sand and gravel percentages. Rolled embankment is generally classified as silty sands and gravels. Areas of rolled embankment in borings C-04-5 and 5A averaged 16 blows/foot. An area of rolled embankment in boring C-04-4 shows about 5% fines and average of 20-25 blows/foot. These correlate to a medium dense granular soil and though similar in gradation to compacted backfill they were assigned lower strength values due to lower blows counts. By using Table II-4, rolled embankment with average N-value of 16 blows/foot was assigned an internal angle of friction (Φ) of 33° which corresponds to a Φ value roughly one third of the way between the Φ value range of 30° to 40° associated with the N-values range of 10 to 30 blows/foot.

6.2.4 Upstream (US) North Abutment Slide Backfill

As-built construction notes, contained in Periodic Inspection Report No. 1, state that due to heavy rains during construction a slide developed in the right upstream abutment. This material was removed to rock and replaced with “rolled embankment.” This slide backfill is approximately 10 feet thick, and lies below 10 to 30 feet of rock fill. This area has been differentiated from rolled embankment due to significantly lower blow counts (N-values) encountered during 2004 drilling. There is no information available in regards to the placement procedures for this material.

Blow counts in boring C-04-14 in the area of this slide backfill averaged 8 blows/foot. This boring was located behind the upstream right retaining wall. Upstream north abutment slide backfill contains less than 15% fines and can be characterized as poorly graded sands with gravel. By using Table II-4, US north abutment backfill with average N-value of 6 blows/foot was assigned an internal angle of friction (Φ) of 28° which corresponds to the lower end of the blow count range for loose granular soils (N-value= 4 to 10).

6.2.5 Rock Fill

Rock fill was placed over slide backfill to the existing grade in the upstream right abutment, most likely due to steep slope geometry and prior slope failure during construction. The rock fill consists of sandstone and limestone from required excavation and ranges from 10 to 30 feet in thickness. Blow counts in the area of rock fill varied, but typically averaged greater than 50 blows/foot. Its assigned shear strength value was based on typical friction angles for angular rock.

6.2.6 Uncompacted Backfill

Uncompacted backfill was placed between excavated soil and the left training wall and between excavated soil and structural concrete on the downstream side of Monoliths 20 and 21. This material was encountered in borings C-04-9 and C-04-11, and generally consisted of 50-60% fines (silts and clays) and N-values that averaged 6-8 blows/foot, correlating to a medium consistency. Uncompacted backfill is similar in soil classification to the in situ soils, and is generally characterized as sandy clays with gravel.

By using Table II-3, uncompacted backfill with N-value of 6 blow/foot was assigned an undrained shear strength value of 800 psf, which roughly midpoint in the range of 500 to 1000 psf as shown in Table II-3 for medium consistency (N-value= 4 to 8). Using Table II-2, uncompacted backfill was assigned an at-rest earth pressure coefficient (K_o) of 0.60, corresponding to lean clay (CL) with overconsolidation ratio (OCR) of 1. Table II-5 lists all selected parameters for uncompacted backfill soils.

6.3 **Groundwater Conditions**

Groundwater levels found during the 2004 drilling program generally coincide with the river elevation just above the soil and bedrock interface, which rises in elevation with distance from the river. Groundwater readings were taken upon completion of each boring; 24-hours readings were recorded in about half of the borings. Installation of several piezometers to evaluate groundwater levels in the abutments is planned following proposed FY-07 undisturbed drilling.

7 **Soil Design Considerations**

7.1 **General**

Engineering properties of soils in both abutments were determined for use in stability analyses for the recommended plan. As stated previously, no shear strength testing was performed on soil samples obtained during the 2004 drilling program. Engineering properties for all known soils at this project have been selected using 2004 drilling and testing data, published correlations involving SPT blow counts, and engineering judgment. At-rest earth pressure coefficients for use in structural analyses have been selected based on empirical relationships to shear strength parameters for granular soils, and engineering judgment for cohesive soils. Six (6) borings are proposed in FY-07 to obtain undisturbed soil samples for testing in order to better define soil strength parameters and stratigraphies necessary for completion of analyses during the design phase of this project.

7.2 **Abutment Soil Stability**

Fill soils placed just upstream and downstream of abutment monoliths enhance monolith stability. As a result, it is necessary to assess the potential for loss of these fills due to slope instability. Slope stability calculations have not been performed during this phase of the project because possible modification of the existing stilling basin and associated training walls which may affect the future abutment slope configurations have not been determined. These will be determined in the design phase following hydraulic physical modeling of the dam by the U.S. Army Engineer Research and Development Center's (ERDC) Coastal and Hydraulics Laboratory.

In reviewing the abutments soils, the following observations have been made:

- Abutment slopes have been stable since completion of construction, spanning a period of about 70 years.
- Abutment fill soils are generally pervious and are likely to provide adequate drainage to prevent slope failures during drawdown following high pools. Exposed impervious in situ soils located on the downstream left abutment are not believed to be pervious due to their percentage of fines (50-60%); however, downstream left abutment slopes are at a 1% grade from the top of the training/retaining wall to El. 885.5, 1V:4H to a berm at El. 902 and 1V:2H slope to the south end of the dam.
- The pool of record (El. 907.35) and subsequent drawdown did not cause slope failures in these areas.
- The upstream right abutment has the steepest slope, but contains approximately 20 feet of rock fill and is buttressed by a retaining wall founded on rock.

For these reasons, it is anticipated that the upstream abutment slopes are stable. However, data from proposed hydraulic physical modeling at ERDC's Coastal and Hydraulics Laboratory is needed to define hydraulic conditions during a PMF level event. Abutment soil stability analyses will be completed during the design phase.

7.3 **Parapet Wall**

Due to pervious subsurface conditions in the upstream right abutment area, underseepage concerns with the proposed upstream parapet wall along its alignment surrounding the

parking area were evaluated. Due to the size and density of these granular soils (poorly graded sands and gravels), piping of material and consequential instability of the wall foundation is not a concern, and thus formal seepage calculations were not performed. A toe drain is proposed to intercept potential seepage and decrease uplift pressures that may damage the asphalt pavement on the dry side of the wall.
The proposed parapet wall on the right abutment is a typical I-wall except for the sub grade portion which is proposed to be founded on drilled H-piles encased in concrete spaced on 6 feet centers. The use of sheet piling may not be practical in this area due to the dense granular soils. Blow counts from boring C-04-4 located near the center of the adjacent parking area ranged from 18-39 blows/foot from the ground surface to a depth of 15 feet and averaged 8 blows/foot from a depth of 15 feet to bedrock.

The proposed parapet wall on left abutment follows along the upstream side of abutment monoliths before heading upstream, paralleling the existing abandoned railway line/walking trail. The elevation of the trail in this area is roughly El. 934 and thus the wall height will be about 4 feet above the existing ground surface. A handicap access ramp is proposed to allow access along the trail where the I-wall crosses to tie into high ground. The random fill required for construction of this ramp will be purchased from a commercial source or possibly onsite excavations.

Borings C-04-13 and C-04-14 drilled along the southeast edge of the trail at the end of the left abutment showed fairly shallow depths to bedrock. An approximate 5-foot thick stratum of heavily weathered shale was encountered at depths of 14 feet and 13 feet in borings C-04-13 and C-04-14, respectively. This is underlain by hard sandstone that extends to approximately El. 890. The overburden in these holes is predominately silty clays with sands and gravels, and exhibited an average N-value of 8 blows/foot correlating to medium stiff to stiff in terms of soil consistency. Underseepage does not pose a threat due to the short wall height and depth of sheet piling for the I-wall. Slope stability was not a concern as the ground slopes at approximate 1V:5H toward the river for about 20 feet from the wall centerline. From there the slope changes to 1V:2.5H. As stated previously, analyses will be performed during the design phase to verify stability.

7.4 State Route 800 Gate Closure

Foundation conditions for the proposed State Route 800 gate closure are unknown at this time. Conditions must be determined to properly design the abutment monoliths and sill as well as prepare plans and specifications. Borings C-04-1 and C-04-2, drilled about 25 feet to the north of the roadway centerline, indicate a relatively shallow bedrock depth beneath the road surface. However, project as-built drawings show that rock dips steeply toward the river. Drilling consisting of overburden sampling and rock coring is planned for the gate closure monolith locations.

7.5 Streambank Erosion Protection

7.5.1 Stone Slope Protection

Bank protection is needed to protect park facilities, SR 800 and abutments against erosion from high flow velocities during significant high water events, which could result in slope instability. High flow velocities during a potential PMF event could undermine the stability of downstream abutment soils which provide resistance to sliding of adjacent monoliths.

The feasibility-level design is to replace the existing riverbank stone slope protection downstream of the stilling basin with graded 36-inch top size stone since the existing stone is estimated to be undersized for a PMF event. This conventional stone slope protection will consist of excavation of existing stone and soil to a stable geometry, installation of a geotextile, and then placement of stone to a thickness of approximately one and a half times its top size or approximately 4.5 feet. The stone shall be keyed in at both the toe and top of the protection and end transitions to prevent outflanking.

As stated previously, hydraulic conditions during a PMF event are unknown at this time but will be determined following hydraulic modeling using scaled physical replicas of the dam by ERDC. Extent and technique of bank treatment will be verified during the design phase. See Appendix C, Tab I, Hydrology and Hydraulics for more detail.

7.5.2 Environmental Design Consideration

The proposed project lies within the range of the clubshell mussel (*Pleurobema clava*), a Federally-listed endangered species. Existence of mussel populations are unknown at this time but will be determined prior to construction following commissioned mussel surveys in partnership with the U.S. Fish and Wildlife Service. Alternative approaches to bank protection are available that would not significantly affect the feasibility or cost assumptions of this report should mussel populations affect the current design. As stated previously, extent and technique of bank treatment will be verified during the design phase. See Section 2.5.3 (Wildlife and Endangered Species) of the main report for more detail.

8 Uplift

The original design assumed uplift of full reservoir head at the heel varying linearly to full tail water head at the toe, but the uplift pressure was assumed to be acting on only 40% of the base. Current guidance assumes uplift acts over 100% of the base and the only reduction allowed is at the line of the drains, called drain efficiency. Drain efficiency represents a reduction in uplift pressures acting upon the base of the dam due to the interception of charged discontinuities by the drains. Current Corps guidance for dams with drains assumes a bi-linear distribution, full reservoir head at the heel varying linearly to a percent reduction at the line of the drains then to full tail water head at the toe (see Figure II-1).

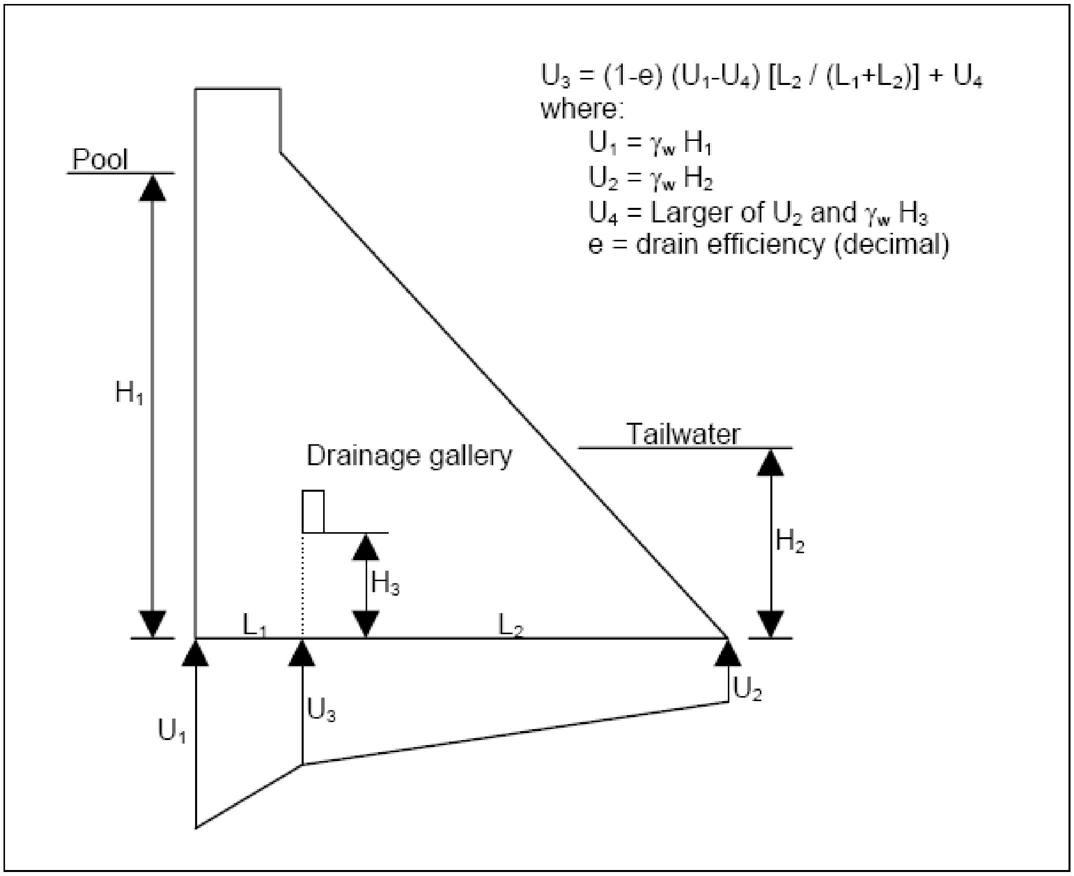


Figure II-1 (from EM 1110-2-2100)

For the 1977 stability reanalysis, the drains at Dover were assumed to be nonfunctional, for this current Evaluation Report it was decided to take a fresh look at the drainage curtain and drain efficiency.

The reduction in uplift due to the drainage curtain (drain efficiency) is based on many factors, some of these include: top of drain elevation, drain spacing, drain depth, and angle of the drain. The following paragraphs compare and contrast the drains at Dover Dam to the ideal, modern drainage system design.

A modern concrete gravity dam is typically designed with two galleries, an upper gallery to facilitate operation of the dam's gates, etc., and a lower inspection (or "drainage" or "grouting") gallery from which the upstream grout curtain and the downstream drainage curtain are constructed, and where uplift pressures are monitored through instrumentation. The ideal drainage curtain would be located in an inspection gallery near the upstream face, and as near the rock surface (in elevation) as feasible to provide the maximum reduction in overall uplift. By locating the inspection gallery at the lowest possible elevation, the drains are more permeable, and by locating it near the upstream face, the reduction in uplift provided by the drains is optimized. Dover Dam has 22 drains located in the Dam's single (operations) gallery in monoliths 4 through 15 with top of drain elevations of 882.25 and 886.25 (see Table II-6.). It should be noted that drain 11 was not drilled into bedrock. The drains in monoliths 7 through 15 intercept bedrock on the downstream bottom of the concrete key, and their top elevations are 53.5 feet above bedrock. Monoliths 4 through 6 (which have no key) have top of drain elevations that average 29.5 feet above bedrock. Due to their location high up in the operations gallery, the drains have a greatly increased head to overcome to reduce uplift. Also, the drains have not been well maintained, in that they have only been cleaned once, during the flood of 2005, by high pressure jetting. The uplift cells were also cleaned at this time in a similar fashion. The uplift-cell data at Dover Dam is questionable. The earliest available records of uplift-cells readings are from a flood event of (elevation 905.0) July 12 of 1969, some 28 years after the dam was constructed. Up until January of 2005 when Dover Dam reached a pool of 907.3 (current pool of record) the 1969 flood was the pool of record. During the 1969 flood, uplift cell number 8 stayed dry, but during the 2005 flood it gave readings near 100% theoretical uplift, and, after being cleaned during the 2005 flood event, this cell gave readings above 100% theoretical uplift. Uplift cells 4 and 5 both showed higher readings in 2005 than in 1969 but not as dramatic. Uplift pressure plots from the 1969 and 2005 flood can be found in Exhibit II-7.

Drains in modern concrete gravity dams are from 3 to 5 inches in diameter, typically spaced at 10-foot intervals, with depths up to 70% of the height of the dam, and are drilled at a slight angle (typically downstream) to increase the likelihood of intercepting near-vertical, open bedrock joints—the most common conduits to the reservoir in relatively flat-lying sedimentary bedrock strata. The drains at Dover are vertical, and are therefore much less likely to intercept vertical bedrock joints. Dover's drains have an average spacing of 20.1 feet and a maximum spacing (between drains 1 and 2) of 35.8 feet; on average, the drains are two times the currently recommended spacing, and in some areas over three times.

Drains must be well maintained to ensure continued functionality. In a modern dam, a maintenance plan would be developed to clean the drains by over-reaming or re-drilling to ensure elimination of mineral crusts, algal slimes, and other blocking materials on a regular interval. The drains at Dover are not considered "well maintained" because they have only been cleaned once in the dams life time, in 2005 (by high pressure jetting), but not followed up with a down-hole imagery to confirm the results.

Drain efficiency. Funding has not been made available to devise or execute an investigative program to estimate the drains' actual contribution to uplift reduction over the base of the dam. If funding was made available, the task would be difficult because the drains at Dover are (elevation 882 and 886) 17 to 21 feet higher than the typical pool elevation of 865.0 and therefore they don't start functioning as drains until the pool is higher than their top elevation. Maintenance of the drains is discussed above. Also, no down-hole imagery has been run down the drains to determine the actual degree to which incrustation has impacted the drains' intersections with bedrock discontinuities. However, as stated earlier the drains were cleaned using high pressure water-jetting in 2005, and 9 of the drains flowed during the pool of record. Therefore, it was deemed prudent to assume that the drains provide some minimal uplift reduction. For this phase of study, a 5% drain efficiency for each drain has been chosen for use in the structural analyses; therefore a monolith with two (2) drains would have 10% drain efficiency, and so on.

Monolith	Drain Number	Top of Drain Elevation	Concrete to Rock Contact Elevation	Drain Hole Depth From Top of Drain (feet)	Drain in Concrete (feet)	Drain in Rock (feet)
4	1	882.25	865	56.8	17.25	39.55
5	2	882.25	848	68.6	34.25	34.35
6	3	882.25	849	69.5	33.25	36.25
	4	882.25	830	69.8	52.25	17.55
7	5	882.25	830	69.7	52.25	17.45
	6	882.25	830	70.5	52.25	18.25
8	7	882.25	830	70.1	52.25	17.85
	8	882.25	830	69.1	52.25	16.85
9	9	882.25	830	69.9	52.25	17.65
10	10	886.25	830	72.7	56.25	16.45
	11	886.25	830	50.5	56.25	-5.75
	12	886.25	830	73.8	56.25	17.55
11	13	886.25	830	73.0	56.25	16.75
	14	886.25	830	73.7	56.25	17.45
12	15	886.25	830	71.7	56.25	15.45
	16	886.25	830	71.5	56.25	15.25
13	17	886.25	835	70.0	51.25	18.75
	18	886.25	835	67.5	51.25	16.25
14	19	886.25	835	74.1	51.25	22.85
	20	886.25	835	71.8	51.25	20.55
15	21	886.25	835	70.0	51.25	18.75
	22	886.25	835	68.5	51.25	17.25

Table II-6 Foundation Drain Data

9 Effect of Anchors on Uplift

The remediation at Dover Dam will require significant anchoring in the spillway and apron for stabilization. The procedure of anchoring will introduce grout into the foundation in quantities that cannot be predetermined. This grout in the foundation can, if added at the right location, help the grout curtain reduce the permeability at the heel, but if injected at or downstream of the drains, such as the multiple rows of anchors needed in the apron, can cause a build up of pressure under the foundation. For the level of study appropriate for this Evaluation Report the drain efficiency will be reduced to 0 percent in those monoliths with anchored aprons, but as part of the Design Document Report, (DDR) the anchoring system of each monolith will be evaluated and the drain efficiency reduced, if deemed appropriate. The anchoring system will be evaluated based on the following parameters:

1) Number of anchors per monolith

2) Location in the foundation of each anchor

3) Diameter of bore hole

4) Grout penetration

5) Monolith width

For design purposes, the monolith foundations will be divided into zones depending upon the degree to which grouted anchors would influence the drain efficiency in that particular area of the foundation. The zones are depicted in Exhibit No. 10. Grout penetration around the anchors is estimated at 8 inches. A drain efficiency reduction factor is calculated for each zone based on the number of anchors, bore hole diameter, grout penetration, and monolith width. Subsequently these per zone reductions (if any) are combined to determine the total reduction for the entire monolith. This percentage value is then applied to the originally assumed drain efficiency to establish the appropriate reduced total efficiency for the monolith.

10 Breach Assumptions

Some of the hydraulics analyses performed for this study required assumptions of the size of breach which might occur during failure. This depends upon several factors: the founding lithology; the depth of the critical sliding plane below the concrete-rock contact, the lateral continuity of open bedding planes and structural discontinuities, and their likelihood of intersection with adversely oriented joints. Based upon the current understanding of the bedrock foundation, it was determined that sliding would occur in the spillway section and could initiate over as little as two to three monoliths, but would quickly spread to include the total width of the spillway due to the highly erodible nature of the shale and siltstone below the limestone. The shale has an average RQD of 51 (see Exhibit II-6

11 Anchor Designs

The anchors needed for stabilizing Dover Dam range up to 61-strand. The project's design currently calls for twenty seven (27) multi-strand anchors and one hundred forty (140) 1-3/8" bar anchors. These anchors are only needed in the spillway monoliths and the apron.

11.1 Corrosion Protection

Because of the serious consequences of failure and the expected service life (50+ years), corrosion protection for the anchors will be Class I, Encapsulated Tendons, as described in the 2004 Post-Tensioning Institute, RECOMMENDATIONS FOR PRESTRESSED ROCK AND SOIL ANCHORS. The tendons shall be 0.6" diameter, 7-wire pre-stressed bare strand throughout the bond length with corrosion inhibiting grease and polypropylene extruded sheathing throughout the stressing length. The anchors shall be fully encapsulated with corrugated HDPE. The 10” corrugated HDPE shall be 90 mil minimum thickness, and all smaller diameter corrugated HDPE to be used for the anchors shall be 60 mil minimum thickness.

11.2 **Anchor Depth Calculation**

“The anchor depth is taken as the anchor length necessary to develop the anchor force required for stability” (EM 1110-1-2908, 30 Nov 94). Simply stated this is the depth below the failure plane at which the potential rock mass failure cones start. For the Dover DSA Project these cones are assumed to start at the mid-point of the bond zone. EM 1110-1-2908 gives multiple formulas for calculating anchor depths, based on the rock mass conditions. There are two formulas given for competent rock that incorporate rock mass cohesion, a single anchor in competent rock (formula 9-1) and a row of anchors in competent rock (formula 9-2). There are three formulas given for fractured rock that incorporate the weight of the rock mass, a single anchor in fractured rock (formula 9-4), and a row of anchors in fractured rock (formula 9-5). Regardless of the condition of the rock mass, there is only one formula for multiple rows of anchors (formula 9-3) and it uses only the weight of the rock mass for the resisting force. The anchors on the Dover DSA Project will be designed on a monolith-by-monolith basis. All of the anchored monoliths will have multiple rows of anchors. Lessons learned from previous anchoring projects show that using formula 9-3 can give anchor depths that are unreasonably long and extremely difficult to construct (see Bluestone Dam example, length 535 feet, in figure II-2). Accepting the lengths required by this formula, the hole alignment specifications would have to be written such that the bore hole could only vary 0.75 of a foot for every 100 feet drilled to ensure that the borings do not intercept. The design team therefore decided to look at other methods of calculating anchor depth which would incorporate only the weight of the rock mass as the resisting force. The chosen methodology, described below and previously applied to the Bluestone DSA project, will be used for the Dover Dam anchors. Stability is analyzed for each monolith individually; therefore, the anchors can be evaluated as a system, on a monolith by monolith basis. A system of anchors can be further broken out into groups when the system of anchors performs more than one function, such as 45 degree anchors to resist sliding and vertical anchors for overturning.

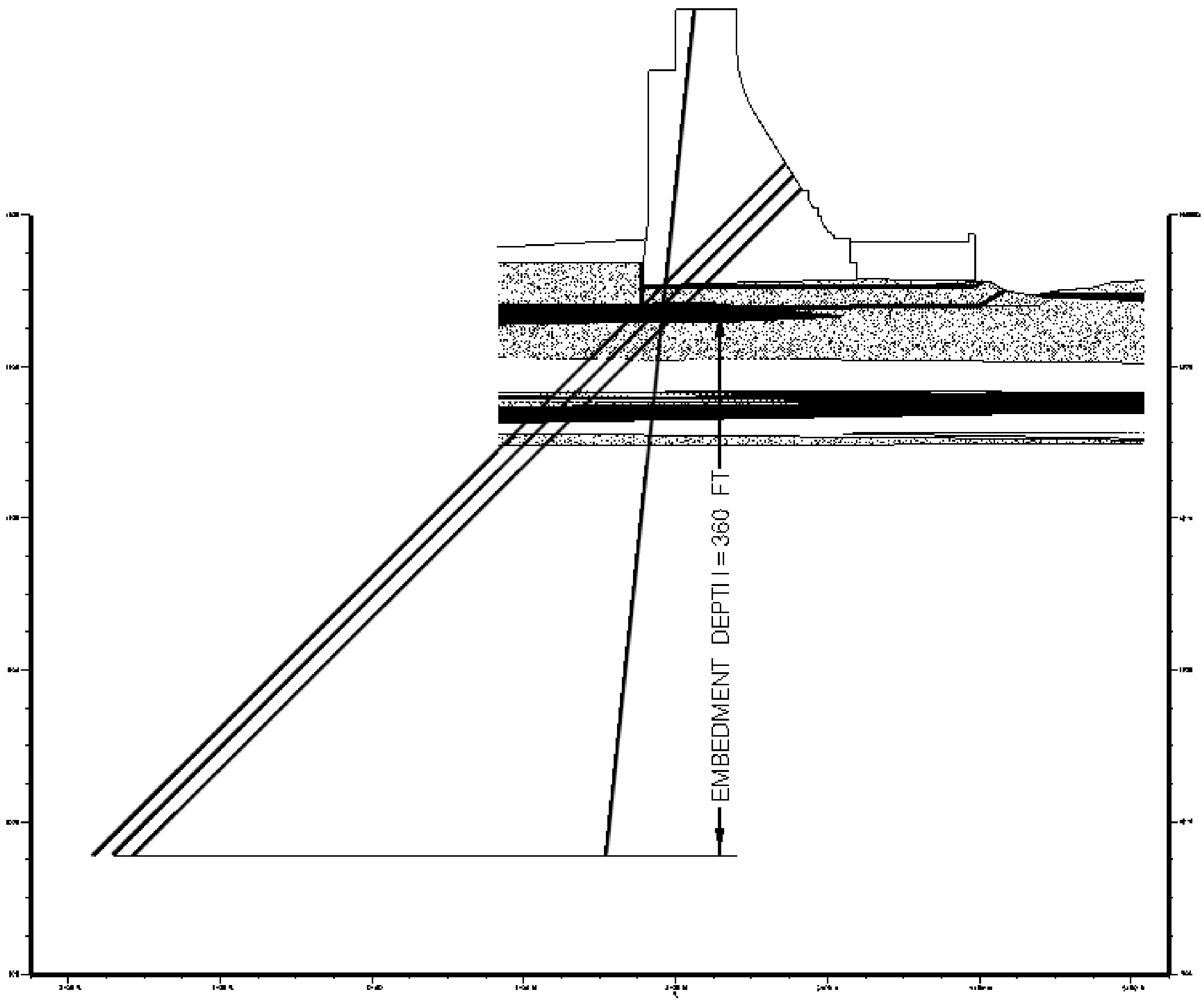


Figure II-2 *(an example of anchor embedment calculated for the BluestoneDam DSA project using EM 1110-1-2908, 30 Nov 94, formula 9-3, the 45 degree anchors have a total length of 535 feet)*

Embedment depths can be designed for a group of anchors by totaling the forces within a group, and using formula 9-4 (single anchor in fractured rock) for each group. Using this approach, the Bluestone monolith depicted in figure II-2 would have an embedment length of only 40 feet below the failure plane for the vertical anchors and 66 feet for the 45 degree anchors. The embedment lengths are checked by creating a 3-D Micro Station drawing of the cones and ensuring that the weight of the cones, using the buoyant weight of rock, equals the force the anchors. The tips of the cones start at the midpoint of the bond zones and go out at 45 degree angles, the cones are constrained at monolith boundaries and failure planes. Also, the 45 degree anchor cones, are stopped at the end of the monolith on the downstream side (see Figure II-3). The volumes are calculated by merging the cones in Micro Station. The resisting weight of the cones is calculated by multiplying the volume by the buoyant weight of rock. When looking at multiple groups of anchors, the cones from each group can and will often overlap, the rock in this overlap area can only be used for one group of anchors and must be subtracted from the other group. The design goal is that the weight of the cones will be at least 1.3 times the force they are opposing. For Dover Dam monolith 7 this methodology gives a resisting weight of 1.8 times the force of the vertical anchors and 2.7 times the force of the 45 degree anchors.

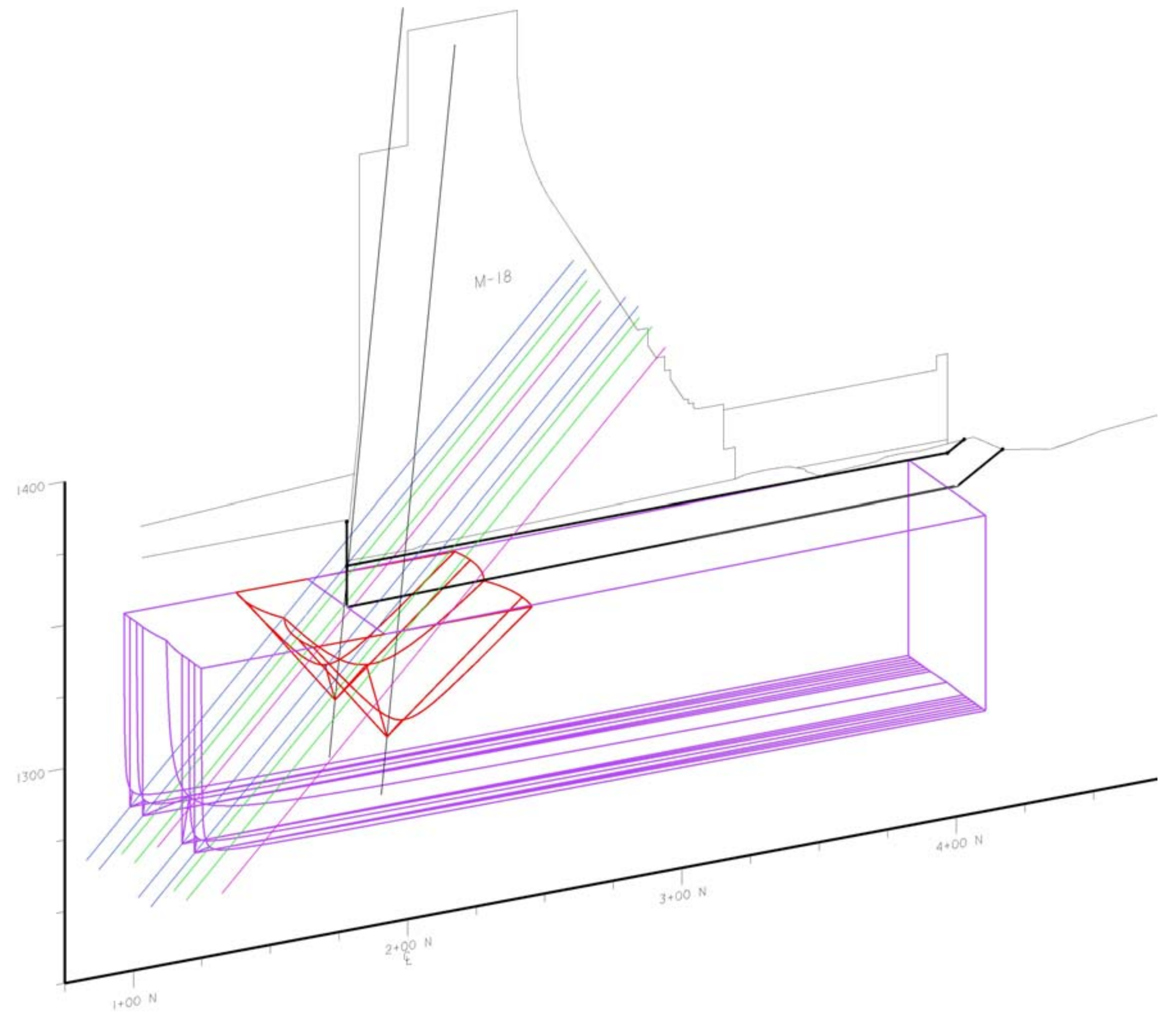


Figure II-3

11.3 **Bond Length Calculation**

Anchor bond length calculations concentrate on the grout to rock bond and not the grout to tendon bond. According to EM 1110-1-2908, 30 Nov 94: “Experience and numerous pull-out tests have shown that the bond developed between the anchor and the grout is typically twice that developed between the grout and the rock." Bond lengths are calculated by using formula 9-6a from EM 1110-1-2908, and vary depending upon hole diameter, grout-to-rock bond strength, and actual loading to be applied. The working bond strength is a weighted average calculated from the material just above and below the embedment depth. At this time no small scale anchor bond pull out tests have been conducted. The grout-to-rock bond strength used for this level of design comes from published strengths in the PTI manual and engineering judgment. The diameter of the hole is dependent on the number of strands and the type of corrosion protection each anchor uses. Bond lengths will be designed as appropriate using formula 9-6a, but the design will ensure that the minimum bond length for anchors is in accordance with the PTI manual recommendations of 15 feet for strand and 10 feet for bars.

12 Future Explorations and Investigations

12.1 Rock

To complete a Detailed Design Report (DDR) additional subsurface exploration and lab testing is needed to adequately characterize the valley bottom, both at the heel and in the apron and apron toe also concrete samples from the dam will be needed, so accurate concrete shear strengths can be assign to the reinforced key and the mass concrete of the dam . Any new features such as anchors, downstream cutoff walls and gate closures that may be a part of the Dover DSA project will also be added to the exploration and testing program.

12.2 Soil

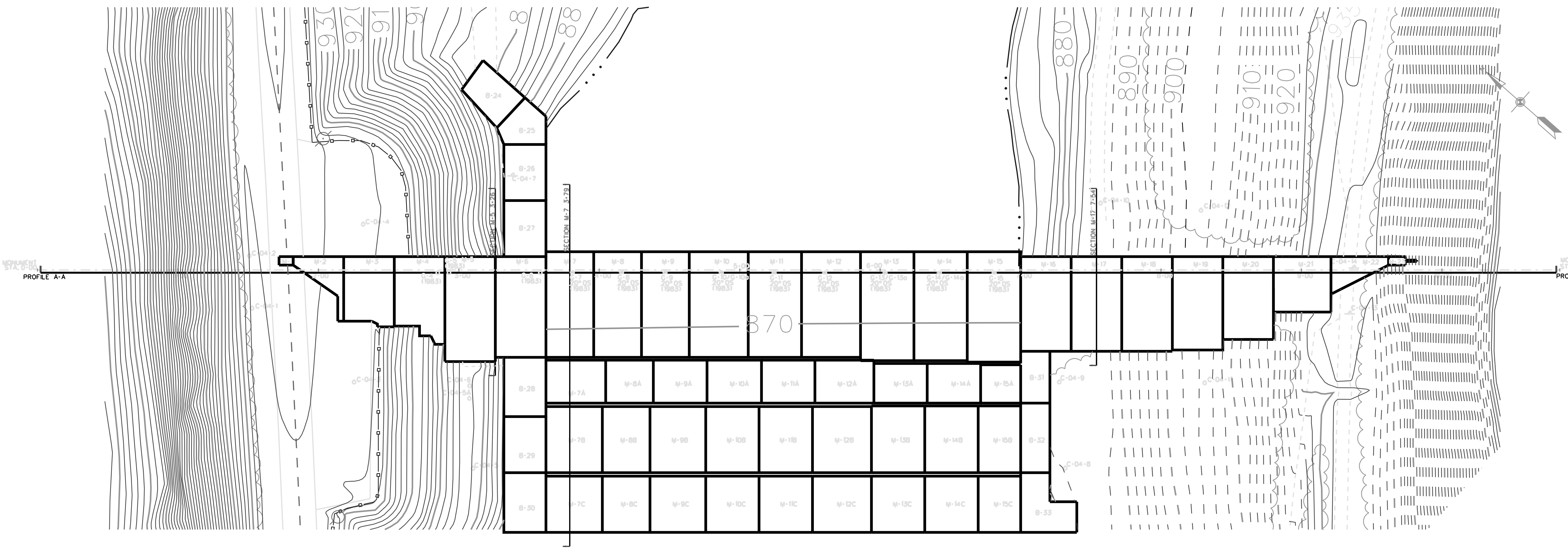
Additional subsurface information is needed to adequately characterize soil stratigraphies and better define the engineering properties of these soils. The designed compositions and placement procedures of in situ project soils and fills are unknown due to limited as-built drawings and no project specifications. The 2004 boring locations were such that they did not provide adequate data for in situ soils and compacted backfill of the downstream left abutment area. All borings performed downstream of the left abutment (C-04-8, 9, and 11) were performed in uncompacted backfill as denoted in as-built drawings. Boring C-04-11 located just downstream of Monolith 20, is in an area labeled as uncompacted backfill on as-built drawings. Both borings C-04-8 and 9 are located in uncompacted backfill behind the left downstream retaining wall. Six (6) borings are proposed in FY-07 to obtain undisturbed soil samples for testing. Following drilling, piezometers will be installed in several holes to monitor groundwater conditions in the downstream abutments.

12.3 Seismic

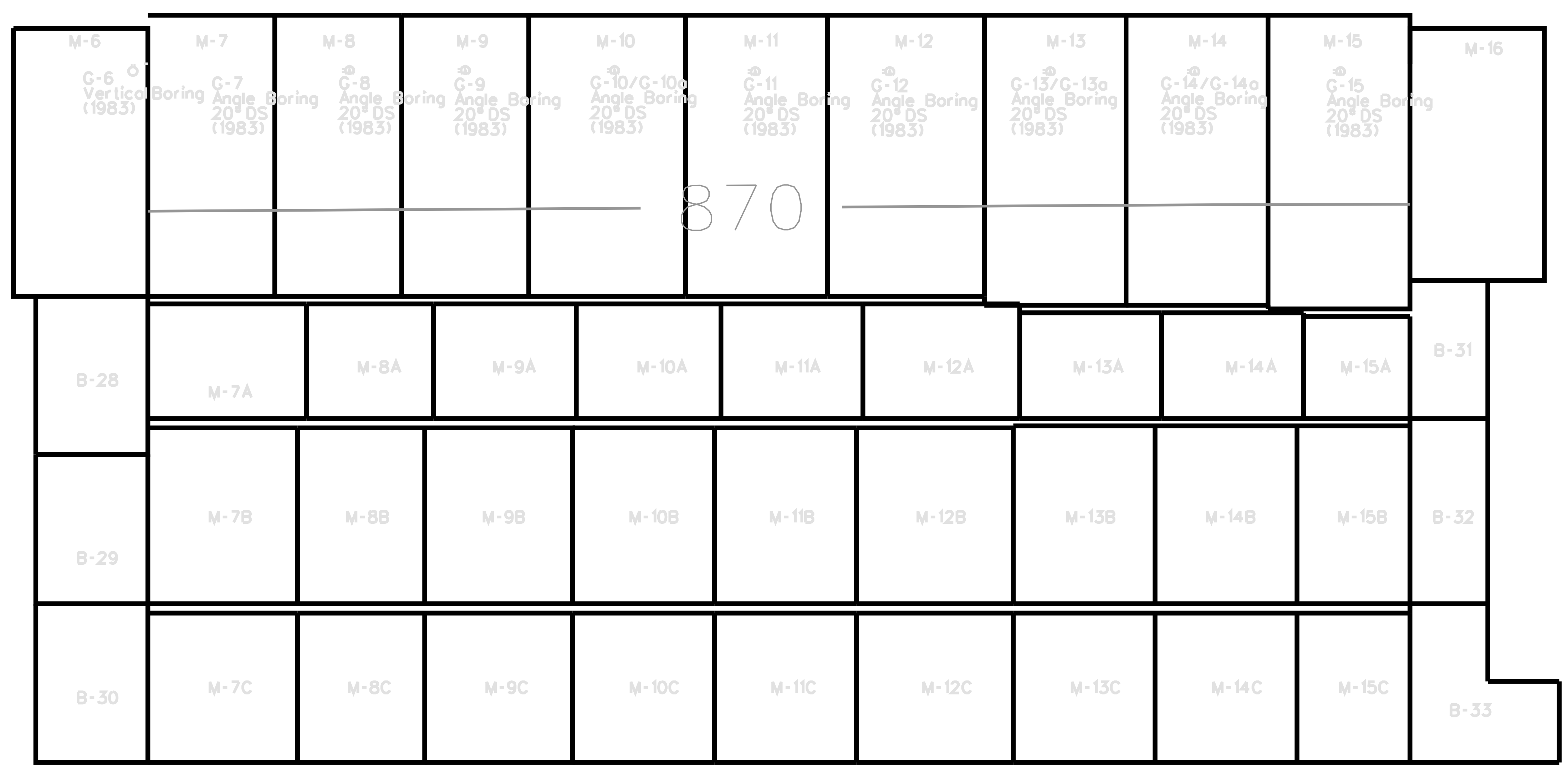
A site and structure specific seismic evaluation will be completed as part of the DDR.

EXHIBIT II-1

BORING LOCATION PLAN



NOTE: BORING LOCATIONS ARE APPROXIMATE.



LEGEND

- Angled Borings
- Vertical Borings

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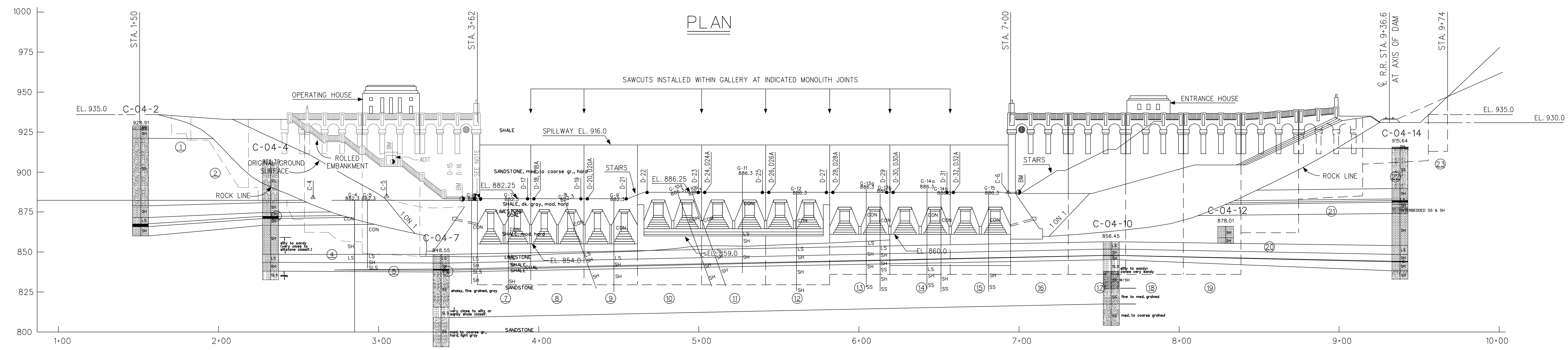
EVALUATION REPORT
BORING LOCATION PLAN

Sheet reference number:
EXH 1
Sheet 1 of 1

EXHIBIT II-2

ROCK PROFILES AND SECTIONS

PLAN



SECTION A-A

Note: See Exhibit II-4 Graphic Logs of Borings for a detailed description of the boring logs.

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TUSCARAWAS RIVER
DOVER DAM
DAM SAFETY ASSURANCE
EVALUATION REPORT
PROFILE 1

Sheet reference number:
EXH 2
Sheet 1 of 4

POTENTIAL FAILURE PLANE SEGMENTS

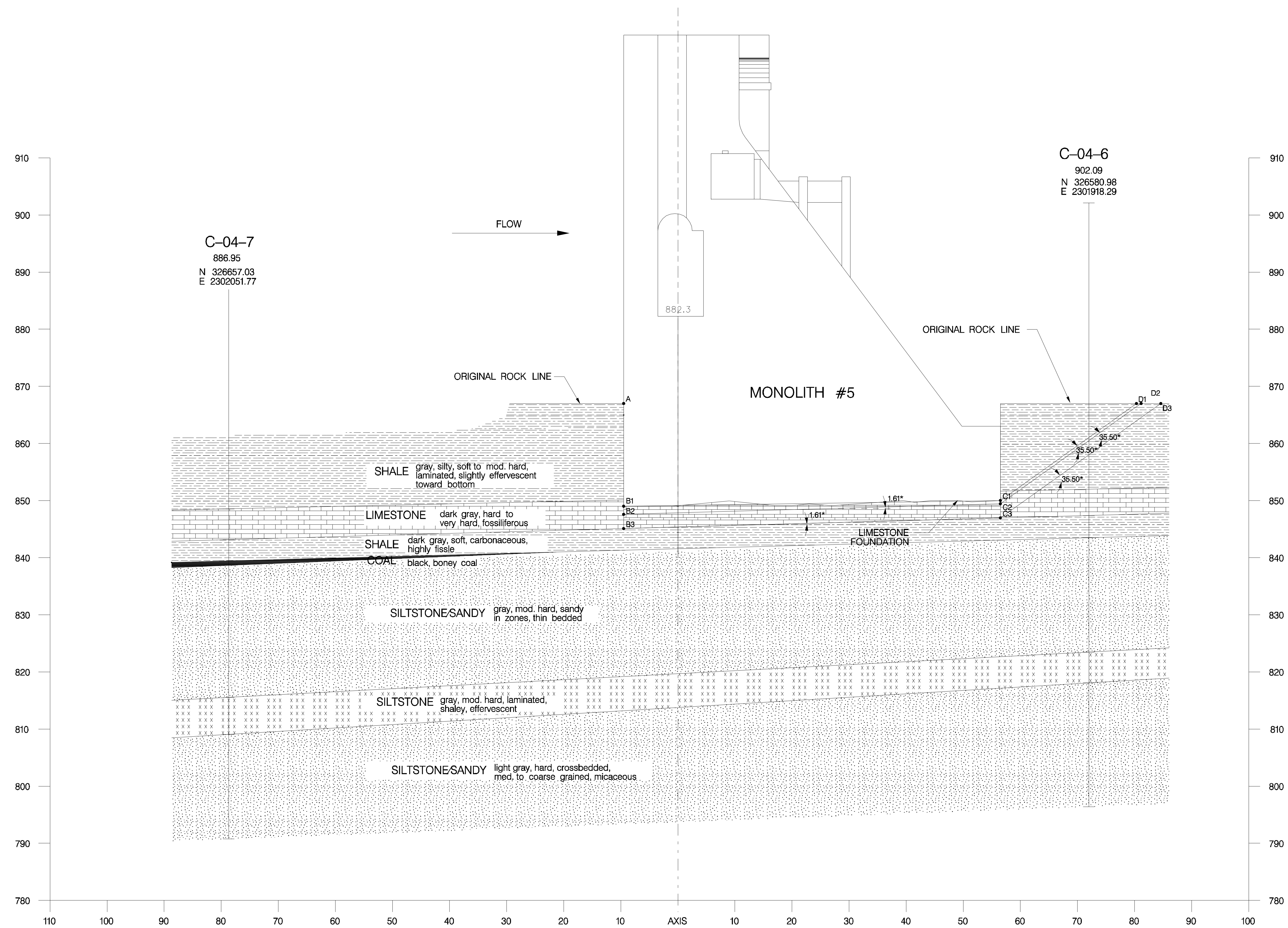
NOTES:

1. Segment identified on cross section with solid line.
2. Analysis of failure plane performed by EC–DS.
3. Segment B1–C1 assumed horizontal.
4. The angle of the base of the passive wedge was defined by the classical Coulomb passive failure plane equation ($45 - \phi/2$).

SLIDING FAILURE MODES	FAILURE PLANE FOLLOWS SEGMENTS:
Stability factor analysis shows adequate factors of safety.	N/A

SEGMENTS	SEGMENT DEFINITION	SHEAR STRENGTH PHI ANGLE (DEG)	COHESION (PSI)	PASSIVE WEDGE FAILURE PLANE ANGLE
A–B1, A–B2, A–B3	Tension Crack	0	0	
B1–C1	Concrete on Rock	50	33	
C1–D1,C2–D2,C3–D3	Fault (as described in foundation report)	19	0	35.50
B2–C2	Limestone	39	7	
B3–C3	Shale	19	1.5	

	Limestone	Shale	Siltstone	Siltstone/Sandy				
WORKING BOND STRENGTH	N/A	N/A psi	N/A psi	N/A				
ALLOWABLE BEARING CAPACITY	2191 psi	300 psi	873 psi	829 psi				
ELASTIC MODULUS (x 10^6)	24.74	1.75	2.75	2.97				
UNIT WEIGHT	168.5 pcf	161.5 pcf	165.8 pcf	159.7 pcf				



MONOLITH #5 (M–5) – SECTION STA. 3+26

Note: The fault in front of Monolith 5 was projected from foundation reports of the adjacent training wall monoliths.

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Ckd by:
Reviewed by: HSB
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EVALUATION REPORT
MONOLITH 5 SECTION

Sheet reference number:
EXH 2
Sheet 2 of 4

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FAILURE PLANE DETAILS
NOTES: 1. Failure plane identified on cross section. 2. Analysis of failure plane performed by EC–DS. 3. The angle of the base of the passive wedge was defined by the classical Coulomb passive failure plane equation (45 – ϕ /2).

SLIDING FAILURE MODES	FAILURE PLANE FOLLOWS SEGMENTS:
Stability factor analysis shows adequate factors of safety.	A, B1, C1, D2, E2

SEGMENTS	SEGMENT DEFINITION	SHEAR STRENGTH PHI ANGLE (DEG)	COHESION (PSI)	PASSIVE WEDGE FAILURE PLANE ANGLE
A–B1, A–B2	Tension Crack	NA	NA	NA
B1–C1	Dam Key (Reinforced Concrete)	38		NA
C1–D1, D1–D2	Shale	19	0.5	NA
D1–E1, D2–E2, D3–E3	Fault (as described in foundation report)	19	0	35.5
B2–D2	Siltstone/Sandy	26	2.0	NA

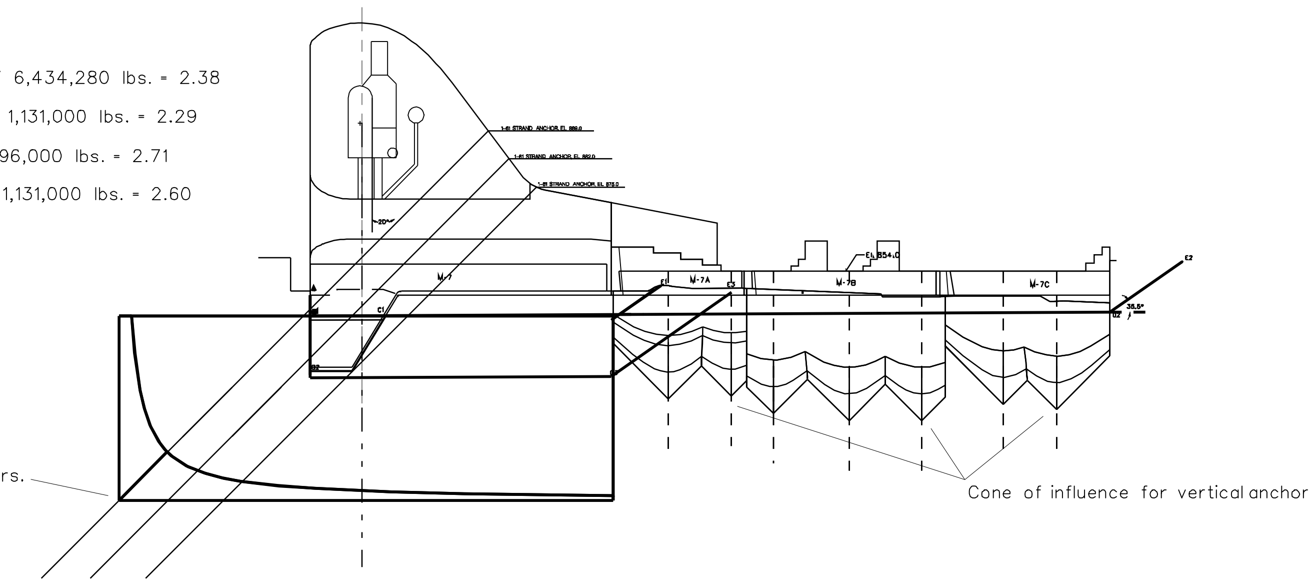
	Limestone	Shale	Siltstone	Siltstone/Sandy				
WORKING BOND STRENGTH	85 psi	50 psi	90 psi	95 psi				
ALLOWABLE BEARING CAPACITY	2191 psi	300 psi	873 psi	829 psi				
ELASTIC MODULUS (x 10^6)	24.74	1.750	2.750	2.970				
UNIT WEIGHT	168.5 pcf	161.5 pcf	165.8 pcf	159.7 pcf				

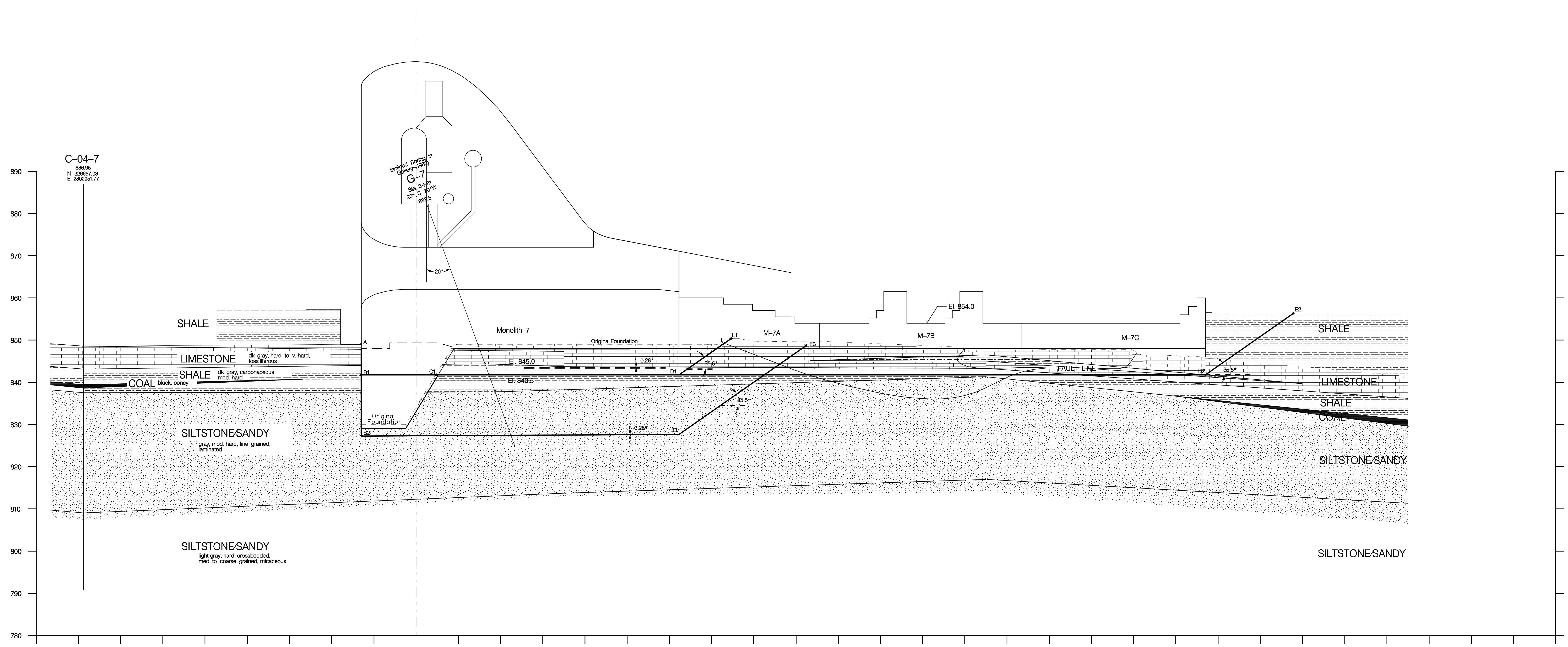
For 45° Anchors
(177518.69 cu. ft. * 97.6 lb./cu. ft.) / 6,434,280 lbs. = 2.38

For Vertical Anchors A
(26,557.8 cu. ft. * 97.6 lb./cu. ft.) / 1,131,000 lbs. = 2.29

For Vertical Anchors B
(47,161 cu. ft. * 97.6 lb./cu. ft.) / 1,696,000 lbs. = 2.71

For Vertical Anchors C
(30,145.6 cu. ft. * 97.6 lb./cu. ft.) / 1,131,000 lbs. = 2.60





MONOLITH #7 (M-7) – SECTION AT STA. 3+79

(MONOLITHS M-7, 7-A, 7-B, & 7-C)

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ENGINEERING GEOLOGY SECTION

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EVALUATION REPORT
MONOLITH 7 SECTION

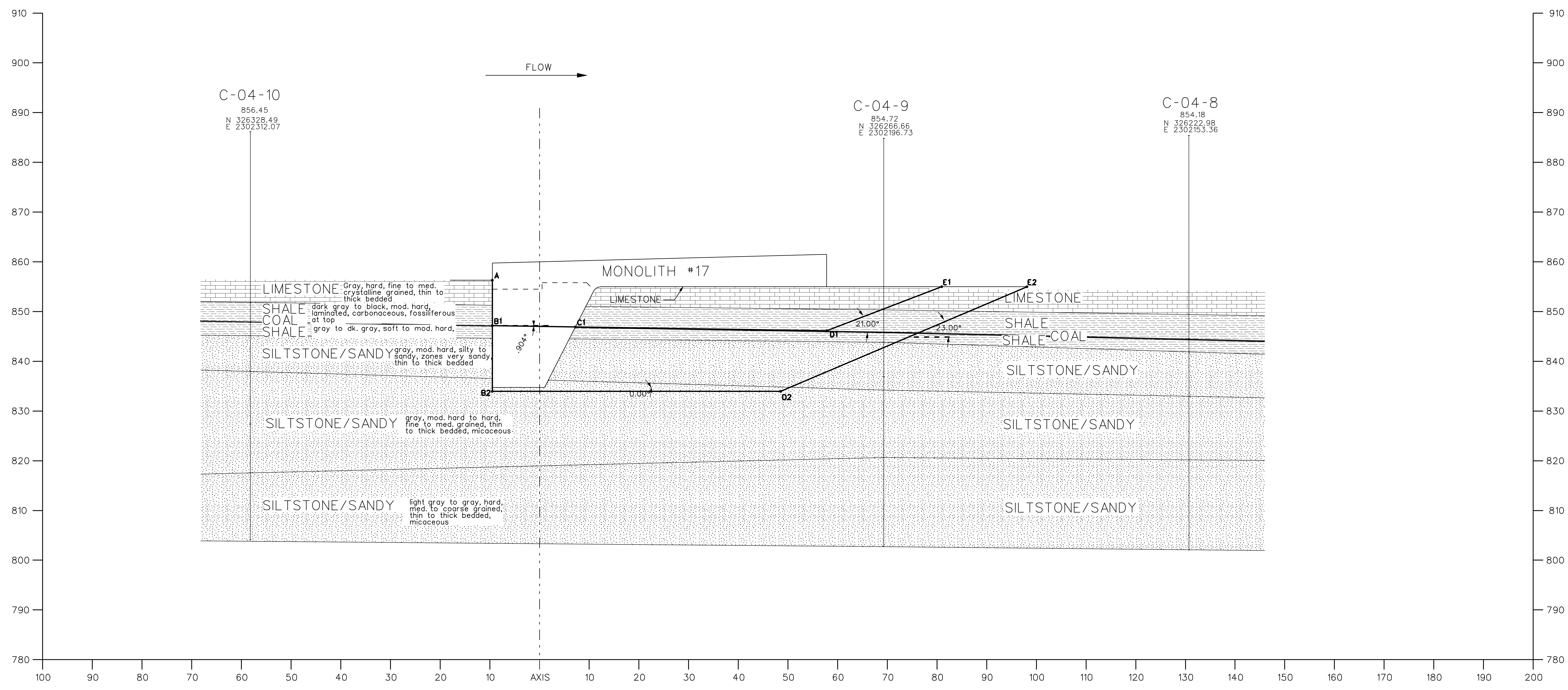
Sheet reference number:
EXH
Sheet 3 of 4

POTENTIAL FAILURE PLANE SEGMENTS
NOTES:
1. Failure plane identified on cross section with solid line. 2. Analysis of failure plane performed by EC–DS 3. Segment B2–C2 is assumed to be horizontal. 4. The angle of the base of the passive wedge was defined by the classical Coulomb passive failure plane equation (45 – ϕ/2).

SLIDING FAILURE MODES	FAILURE PLANE FOLLOWS SEGMENTS:
Stability factor analysis shows adequate factors of safety.	N/A

SEGMENTS	SEGMENT DEFINITION	SHEAR STRENGTH PHI ANGLE (DEG)	COHESION (PSI)	PASSIVE WEDGE FAILURE PLANE ANGLE
A–B1, A–B2	Tension Crack	NA	NA	
B1–C1	Concrete Key	38		
C1–D1	Shale	19	0	
D1–E1	Passive Wedge	48	80	21
B2–D2	Siltstone/Sandy	25	1.8	
D2–E2	Passive Wedge	45	45	23

	Limestone	Shale	Siltstone	Sandy Siltstone				
WORKING BOND STRENGTH	NA	NA	NA	NA				
ALLOWABLE BEARING CAPACITY	2191	300 psi	873 psi	829 psi				
ELASTIC MODULUS (x 10^6)	24.74	1.75	2.75	2.97				
UNIT WEIGHT	168.5 pcf	161.5 pcf	165.8 pcf	159.7 pcf				



MONOLITH #17 (M-17) - SECTION AT STA. 7+54

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	Submitted by:	File name: B-SCGm17.dgn Plot date: Plot scale:	

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EVALUATION REPORT
MONOLITH 17 SECTION

Sheet reference number:
EXH 2
Sheet 4 of 4

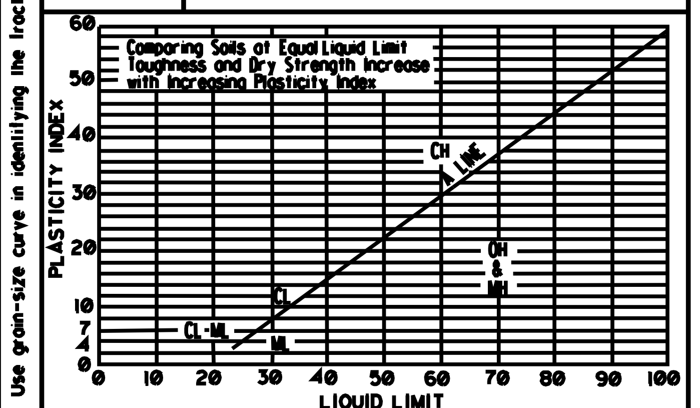
EXHIBIT II-3

GEOLOGY AND SOILS LEGEND

UNIFIED SOIL CLASSIFICATION

Including Identification and Description

MAJOR DIVISIONS 1	MAJOR DIVISIONS 2		GROUP SYMBOLS 3	TYPICAL NAMES 4	FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights) 5	INFORMATION REQUIRED FOR DESCRIBING SOILS 6	LABORATORY CLASSIFICATION CRITERIA 7
COARSE - GRAINED SOILS More than half of materials is larger than No. 200 sieve size (The No. 200 sieve size is about the smallest particle visible to the naked eye.)	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4-inch sieve size may be used as equivalent to the No. 4 sieve size.)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.	Determine percentages of gravel and sand from grain size curves. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows: Less than 5% GW, GP, SW, SP; More than 12% GM, GC, SM, SC; 5% to 12% Borderline cases requiring use of dual symbols. — $C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		Not meeting all gradation requirements for GW
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Give typical name; indicate approximate percentage sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.	Atterberg limits below "A" line or PI less than 4 — Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		Atterberg limits above "A" line with PI greater than 7
	SANDS More than half of coarse fractions is smaller than No. 4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3
			SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	EXAMPLE Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. max. size; rounded and subangular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand (SM).	Not meeting all gradation requirements for SW
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		Atterberg limits below "A" line or PI less than 4 — Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		Atterberg limits above "A" line with PI greater than 7
					Fraction Smaller than No. 40 Sieve Size: DRY STRENGTH (crushing) / DILATANCY (reaction to shaking) / TOUGHNESS (consistency near PL)		
FINE - GRAINED SOILS More than half of materials is smaller than No. 200 sieve size	SILTS AND CLAYS Liquid Limit Less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight / Quick to slow / None	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses.	Use grain-size curve in identifying the fractions as given under field conditions.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high / None to slow / Medium		
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium / Slow / Slight	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.	
	SILTS AND CLAYS Liquid Limit Greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium / Slow to none / Slight to medium		
			CH	Inorganic clays of high plasticity, fat clays.	High to very high / None / High	EXAMPLE Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess (ML)	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high / None to very slow / Slight to medium		
Highly Organic Soils			PI	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		



PLASTICITY CHART

For laboratory classification of fine-grained soils

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder (2) All sieve sizes on this chart are U.S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. for field classification purposes. screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

DILATANCY (reaction to shaking)
After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour show a moderately quick reaction.

DRY STRENGTH (crushing characteristics)
After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water, if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking or crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic of clays in the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

TOUGHNESS (consistency near plastic limit)
After removing particles larger then the No. 40 sieve size, a specimen of soil about one-half inch cube in size is molded to the consistency of putty. If too dry, water must beadded and if sticky, the specimen should be spread in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.
Highly organic clays have a very weak and spongy feel at the plastic limit.

Adopted by the Corps of Engineers and Bureau of Reclamation, January 1952.

BEDROCK DESCRIPTORS

HARDNESS

Very Soft – Can be deformed by hand
Soft – Can be scratched with fingernail
Moderately Hard – Can be scratched easily with a knife
Hard – Can be scratched with difficulty with a knife
Very Hard – Cannot be scratched with a knife

THICKNESS OF BEDDING

Massive – Beds 3 feet thick or greater
Thick Bedded – Beds from 1 to 3 feet thick
Medium Bedded – Beds from 4 inches to 1 foot thick
Thin Bedded – Beds 4 inches or less

GRAIN SIZE

Boulders – •305 mm diameter
Cobbles – 305 - 76 mm diameter
Gravel – 76 - 5 mm diameter
Coarse Grained – 5 - 2 mm diameter
Medium Grained – 2 - 0.4 mm diameter
Fine Grained – 0.4 - 0.1 mm diameter
Very Fine Grained – 0.1 mm diameter

LIGHT GRAY REDUCTION SPOT FREQUENCY

Few – Greater than 1/2-inch spacing between reduction spots with diameters of 0.01' or greater
Numerous – 1/2-inch spacing or less between reduction spots with diameters of 0.01' or greater

BROKEN OR FRACTURED CORE

Severely Broken – Broken core pieces can not be reconstructed, gravel-sized pieces, core loss common
Moderately Broken – Broken core pieces can be reconstructed with some difficulty
Slightly Broken – Broken core pieces can be reconstructed easily

DEGREE OF WEATHERING

Unweathered – No evidence of any chemical or mechanical alteration
Slightly Weatherd – Slight discoloration on surface, slight alteration along discontinuities, less than 10% of the rock volume altered
Moderately Weathered – Discoloring evident, surface pitted and altered with alteration penetrating well below rock surfaces, weathering "halos" evident, 10% to 50% of the rock altered
Highly Weathered – Entire mass discolored, alteration pervading nearly all of the rock with some pockets of slightly weathered rock noticeable, some minerals leached away
Decomposed – Rock reduced to a soil with relict rock texture, generally molded and crumbled by hand

DISCONTINUITY SURFACE

Very Rough – Near vertical ridges occur on the discontinuity surface
Rough – Some ridges are evident; asperities are clearly visible and discontinuity surface feels very abrasive
Slightly Rough – Asperities on the discontinuity surface are distinguisable and can be felt
Smooth – Surface apperars smooth and feels so to the touch
Slickensided – Visual evidence of polishing exists
Planar – Flat shaped discontinuity surface
Irregular – Undulant or unevenly shaped discontinuity surface

GENERAL BEDROCK DESCRIPTION

Bedrock at the Soo project is sandstone of the late Precambrian-aged Jacobsville Sandstone Formation. For engineering purposes this formation has been classified into four major members. These members include: Hard Sandstone, Moderately Hard Sandstone, Weathered Sandstone and Shaly Sandstone. Within these sandstone members are thinner seams of clay, claystone and shale.

Hard Sandstone member is typically light gray, light red or light purple with few light gray reduction spots, hard to very hard, fine to medium grained occasionally cross bedded and medium to thick bedded.

Moderately Hard Sandstone member is typically red with few to numerous light gray reduction spots, moderately hard, fine to medium grained and thin to medium bedded.

Weathered Sandstone member is typically red with numerous light gray reduction spots, moderately hard, fine to medium grained, moderately weathered and thin bedded.

Shaly Sandstone member is typically red to dark red with light gray reduction spots, soft to moderately hard, fine grained and thin bedded.

BEDROCK SYMBOLS

SS_h - HARD SANDSTONE	SS_w - WEATHERED SANDSTONE	SH - SHALE	CON - CONCRETE
SS_m - MODERATELY HARD SANDSTONE	SS_{sh} - SHALY SANDSTONE	CLS - CLAYSTONE	LS - LIMESTONE

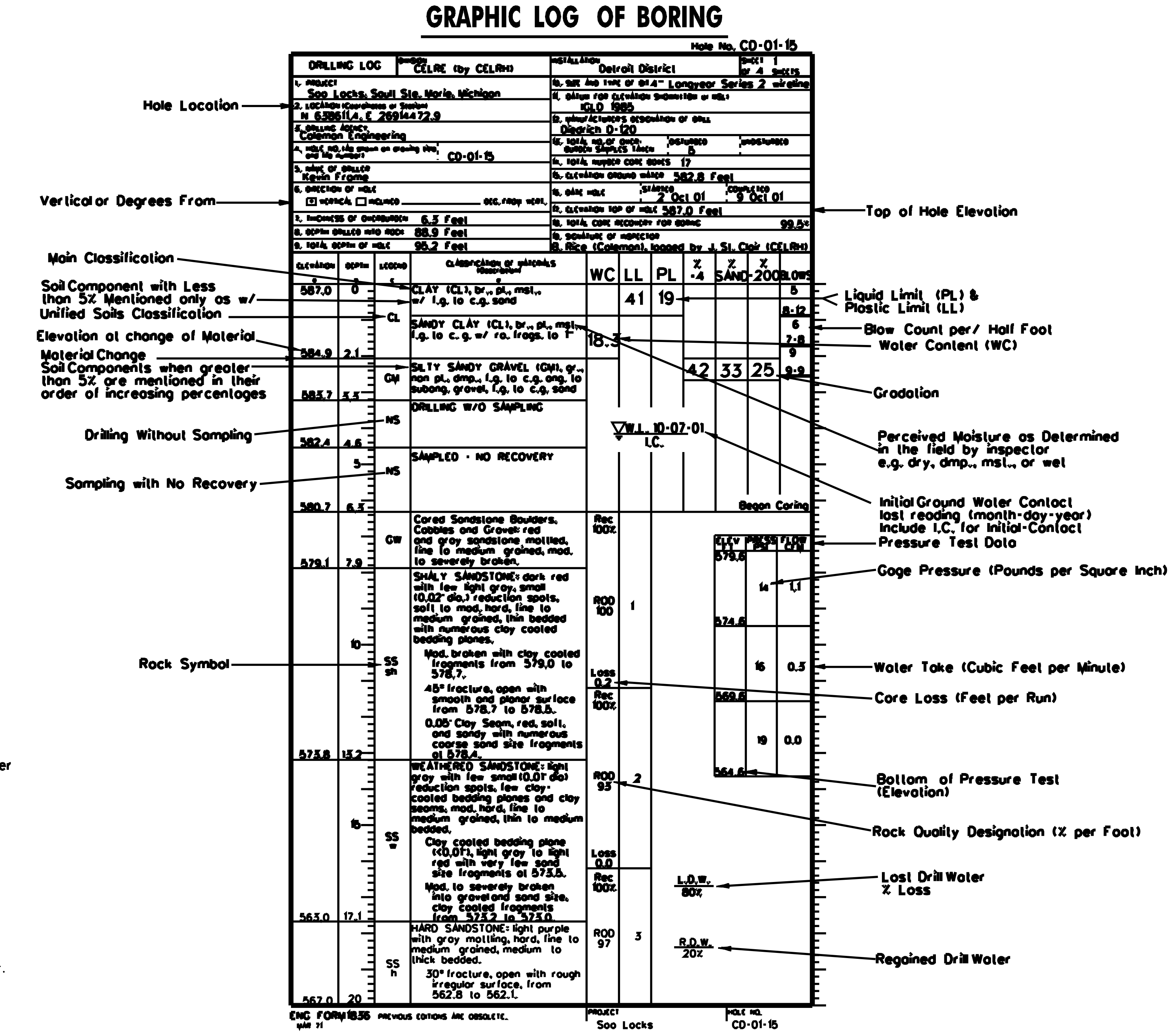
ABBREVIATIONS

a.	angle	f.	fine	mot.	mottled	str.	stringer(s)
alt.	alternate(ly)(ing)	fer.	ferruginous	mst.	moist	sty.	stylolite(ic)
amt.	amount	fis.	fissile	mtx.	matrix	t.	thin
ang.	angular	fil.	fill(ed)(ing)	n.	near	tho.	throughout
approx.	approximate(ly)	fm.	firm	nod.	nodule(s)	tk.	thick
ar.	argillaceous	fos.	fossil(iferous)	num.	numerous	tr.	trace
aren.	arenaceous	frac.	fracture(d)	o.	open	v.	variably
asp.	asphaltic	frags.	fragment(s)(al)	od.	odor	va.	variegated
b.	bone	fri.	friable	occ.	occasional(ly)	ve.	very
ba.	banded(ing)	FP	fixed-piston	occu.	occurring	veg.	vegetation
bd.	bed(ed)(ing)	FW	free water	org.	organic	ver.	vertical(ly)
bdr.	bedrock	g.	grain(ed)	pa.	parting(s)	vu.	vuggy
bf.	buff	gen.	generally	part.	particle(s)	w.	water
bk.	black	gn.	green(ish)	%	percent(age)	w/	with
bky.	blocky	gr.	gray	pi.	piece	w/o	without
bkn.	broken	gra.	gravelly	pl.	plastic	WC	water content
bl.	blue	grad.	grading(ed)	PL	plastic limit	wd.	weathered
bot.	bottom	GW	groundwater	peb.	pebble(s)	WH	weight of hammer
bou.	boulder(s)	h.	hard	pk.		whi.	white
bre.	breccia(ted)	ha.	high angle	pkt.	pocket(s)	WL	water level
br.	brown(ish)	hi.	high(er)(ly)	pit.	pit(ted)(ting)	wo.	wood
c.	coarse	hor.	horizontal(ly)	pn.	plane(s)	x-bd.	cross-bedded(ing)
ca.	calcareous	IC	initial contact	po.	porous	y.	yellow(ish)
carb.	carbonaceous	inc.	included, inclusions	pt.	part(ly)	z.	zone
cav.	cavern, cavity	incr	increasing(ly)	pyr.	pyrite(ic)		
cbl.	cobble(y)	inta.	interlaminated	q.	quartz(itic)		
ch.	chert	int.	intercalations	r.	red(dish)		
cl.	clay(ey)	intbd.	interbedded	ro.	rock(s)		
clb.	claybands	irr.	irregular	rol.	rolled(en)		
cle.	clean	jt.	joint(ed)	rou.	round(ed)		
coa.	coal(ed)(ing)	l.	low	rt.	root(s)(let)		
comp.	compact(ed)	li.	little	s.	soft		
con.	contains	la.	low angle	SS	split spoon		
conc.	concretion	las.	laminate(ed)(ions)	sa.	sandy		
cong.	conglomerate(ic)	lay.	layer(s)	sat.	saturated		
cont.	continuous	le.	lean	scat.	scattered		
cr.	crushed	lea.	leached	se.	seams		
crm.	crumbly	len.	lense(s)	sev.	severe(ly)		
cst.	crystal(line)	lg.	large	sevr.	several		
cem.	cement(ed)	LL	liquid limit	sh.	shaly		
dc.	decayed	los.	loose	she.	shells		
di.	dirty	lt.	light	sil.	siliceous		
dia.	diameter	m.	medium	sl.	silty		
diag.	diagonal	ma.	many	slk.	slickensided		
dis.	disintegrated	mas.	massively	sm.	small		
disc.	discontinuous	mat.	material	so.	some		
diss.	disseminated	mic.	micaceous	sol.	solution		
dk.	dark	min.	mineralized	sta.	stain(ed)		
dn.	dense	mod.	moderate(ly)	stf.	stiff		
dmp.	damp	mos.	mostly	stks.	streak(s)		
ext.	extremely						
elem.	elements						

NUMBER AND TYPE OF EXPLORATIONS

CODE	YEAR	HOLE NO.	DESIGNATION
C	98	52	Core hole in bedrock
D	98	31	Disturbed sample boring
CD	98	69	Boring with disturbed sampling in soil and coring in bedrock.
UD	98	31	Undisturbed sample boring
			Core hole in bedrock, hydraulic pressure tested
			Indicates angle boring and direction
			Boring with Piezometer
			Proposed Exploration
TP	98	15	Test Pit in overburden
TT	98	6 - 135	Test Trench in overburden (TT-98-6), soils classified at stationing as shown (135 feet)
UD	98	39	Undisturbed sample boring with Piezometer
			Disturbed Sample Boring with Piezometer
			Washbored
			Cone Penetrometer Hole
			Boring with Inclinometer
			Boring with disturbed sampling in soil and coring in bedrock, with a Piezometer.
			Boring with disturbed sampling in soil and coring in bedrock, and hydraulic pressure tested.
			Boring with disturbed sampling in soil and coring in bedrock, hydraulic pressure tested, with a Piezometer.

GRAPHIC LOG OF BORING



US Army Corps of Engineers Huntington District

U.S. ARMY CORPS OF ENGINEERS HUNTINGTON DISTRICT HUNTINGTON, WEST VIRGINIA

Designed by: EC-G | Dwn by: DKP, DAW | Ckd by: SCL | Reviewed by: AWK | Submitted by: | File name: B00ILG1.dgn

TUSCARAWAS RIVER DOVER, OH DOVER DAM DAM SAFETY ASSURANCE

GEOTECHNICAL GEOLOGY AND SOILS LEGEND

Sheet reference number: EXH 3 Sheet 1 of 1

EXHIBIT II-4

GRAPHIC LOGS AND BORINGS

DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 2 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-4	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olsen	14. TOTAL NUMBER CORE BOXES 2
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 873.1
	16. DATE HOLE: STARTED 11-19-82; COMPLETED 12-02-82
7. THICKNESS OF OVERBURDEN 00.0 Feet	17. ELEVATION TOP OF HOLE 882.3
8. DEPTH DRILLED INTO ROCK 14.3 Feet	18. TOTAL CORE RECOVERY FOR BORING 99.7 %
9. TOTAL DEPTH OF HOLE 37.1 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Natural gravel aggregate. Rounded 2 inch maximum diameter gravel. 0.2' Zone of poorly cemented aggregate at 876.2 to 876.0.			100% Drill recovery in concrete Concrete retained for record see G-5 Boxes A&B
862.3	20.0					

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MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-4

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-4
PROJECT Dover Dam Gallery	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
860.5	21.8					Began Coring
859.5	22.8		Top of Rock	Rec 100%		Good concrete to rock bond.
		SH	SHALE: Silty, moderately hard dark gray, moderately to highly fissle with numerous fine, light gray sandy lenses. 0.5' unweathered, severely broken high angle fracture from 859.4'-858.9'.	Loss 0.0 Rec 100% Loss 0.0 Rec 98%	1	Porting in Shale 0.05' below Concrete/Rock contact.
849.2	33.1	LS	LIMESTONE: Hard, dark gray fossiliferous, thick bedded.	Loss 0.1 Rec 100% Loss 0.0	2	
845.2	37.1		Bottom of Hole			

DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 2 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-5	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0 ; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER: 872.1
	16. DATE HOLE: STARTED 12-08-82 ; COMPLETED 12-09-82
7. THICKNESS OF OVERBURDEN: 0.0 Feet	17. ELEVATION TOP OF HOLE: 882.3
8. DEPTH DRILLED INTO ROCK: 8.9 Feet	18. TOTAL CORE RECOVERY FOR BORING: 99.5 %
9. TOTAL DEPTH OF HOLE: 42.2 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Natural, rounded gravel aggregate up to 3 inch maximum diameter.			
						100% Drill recovery in concrete.
						Concrete cored and discarded from 882.3' to 851.5'.
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
		CON				
862.3	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio | HOLE NO. G-5

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-5
PROJECT Dover Dam Gallery	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			Concrete, see G-5, Box C 25° cold joint @ 854.1
851.5	30.8					Began Coring
				Rec 100%		
849.0	33.3		Top of Rock			Open at concrete to rock contact.
		LS	LIMESTONE: Hard, dark gray fossilferous, medium to thick bedded. 0.8' unweathered, near vertical fracture 847.3 to 846.5 0.6' open, stained, high angle fracture 846.4 to 845.8 Open bedding plane with same grout coating at 845.8 0.2' open, low angle fracture with grout coating at 845.6 Gradational Contact at 849.0 (open contact with rock) next parting 847.0	Loss 0.0 Rec 96%	1	
844.5	37.8	SH	SHALE: Soft to moderatly hard, clayey, very dark gray, highly fissle. Unweathered, low angle joint at 843.8 0.2' Broken zone along fracture with 0.2' loss at 842.4 to 842.0 Gradational contact between Shale and Siltstone.	Loss 0.2		
841.2	41.1	SLS	SILTSTONE: Moderatley hard, gray, sandy in zones, thin bedded.	Rec 100% Loss 0.0		
840.1	42.2		Bottom of Hole			

DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-6	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olsen	14. TOTAL NUMBER CORE BOXES 0
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 870.9
	16. DATE HOLE: STARTED 12-09-82; COMPLETED 12-15-82
	17. ELEVATION TOP OF HOLE 882.3
7. THICKNESS OF OVERBURDEN 00.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 98.6 %
8. DEPTH DRILLED INTO ROCK 17.4 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.
9. TOTAL DEPTH OF HOLE 52.2 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Natural, rounded gravel aggregate up to 3 inch maximum diameter.			100% Drill recovery on all Concrete. No unusual broken zones. Concrete cored and discarded from 882.3' to 852.7'
		CON				
862.3	20.0					

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MAY 04

PROJECT Dover Dam, Ohio — HOLE NO. G-6

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 882.3 | Hole No. G-6

PROJECT Dover Dam | INSTALLATION HUNTINGTON DISTRICT | SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
852.7	29.6					Began Coring
			CONCRETE: Natural sediment aggregate, some vuggy zones.	Rec 100%		Open at Contact (core spun) Next parting 848.4'
848.5	33.8		Top of Rock	Loss 0.0		
		LS	LIMESTONE: Hard, dark gray, fossiliferous, medium bedded.	Rec 96%	1	
843.8	38.5					
		SH	SHALE: Moderately hard to hard, dark gray clayey, thin bedded, highly fissle. Fracture, open, planar, smooth from 843.0' to 842.7'. Vertical fracture, open, rough irregular from 842.2' to 842.1'	Loss 0.2 Rec 100%		
840.8	41.5					
		SLS	SILTSTONE: Moderately hard to hard, gray, thin bedded, with Shaly zones and zones of fine grained Sandstone. 0.4' Shale, clayey, dark gray at 838.5 to 838.1 2.5' Sandstone, silty, at 838.1			
838.3	44.0			Loss 0.0		

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam, Ohio | HOLE NO. G-6

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 882.3 | Hole No. G-6

PROJECT Dover Dam | INSTALLATION HUNTINGTON DISTRICT | SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SLS	SILTSTONE: (Continued) Thin bedded, moderately broken from 838.5' to 838.1'	Rec N/A		Recovery data not recorded.
835.6	46.7	SLS	SILTSTONE: Moderately hard, shaley and sandy gray, moderately fissle, with thin sandstone zones. 0.5' Sandstone, fig., at 834.4 to 833.9 Moderately broken and thin bedded from 831.7' to 831.4' Severely broken, crushed to gravel and pebble sized pieces from 830.6' to 830.3'		2	
830.1	52.2		Bottom of Hole	Loss N/A		

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-6

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: Impregnated and Diamond NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-7	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olson	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER: 874.0 - 871.4
	16. DATE HOLE: STARTED 01-11-83; COMPLETED 01-14-83
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 882.3
8. DEPTH DRILLED INTO ROCK: 33.6 Feet	18. TOTAL CORE RECOVERY FOR BORING: 98.2 %
9. TOTAL DEPTH OF HOLE: 61.1 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Pea gravel aggregate and some chert fragments.			Concrete was cored and discarded from 882.3' to 850.4'.
863.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio | HOLE NO.: G-7

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-7
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
850.4	34.0					Began Coring
			Concrete retained from 850.4' to 848.7'	Rec 100%		Core diameter loss to 849.8'
848.7	35.8		Top of Rock			
		LS	LIMESTONE: Dark gray to black, hard with laminated seams, fossiliferous. Severely broken zone from 845.9' to 845.5' 85° fracture, rough and irregular from 845.9' to 845.4'	Loss 0.0		
				Rec 96%	1	
844.2	40.5					
		SH	SHALE: Black, moderately hard. Severely broken, crushed, and weathered zone with multiple open bedding planes and incipient fractured zone appears to be pulverized with pieces the size of pebbles and small gravel from 842.0' to 841.4'	Loss 0.2		
840.9	44.0					

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-7
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
840.9	44.0	SLS	SILTSTONE: Sandy, dark gray into gray, moderately hard to hard, sandier with depth. Severely broken and fractured with mulitple high angle fractures and open bedding planes 0.02' spacing between from 835.3' to 833.5, 833.2' to 832.6', 832.2' to 830.8', 830.6' to 830.1', 829.6' to 828.9', 828.7' to 827.3', 826.5' to 824.9'	Rec 100% Loss 0.0		
				Rec 96% Loss 0.2	2	
				Rec 98% Loss 0.1		
				Rec 100% Loss 0.0		
824.8	61.1		Bottom of Hole			

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam, Ohio | HOLE NO. G-7

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olson	14. TOTAL NUMBER CORE BOXES 2
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER 872.7 - 870.3
	16. DATE HOLE: STARTED 01-17-83; COMPLETED 01-21-83
	17. ELEVATION TOP OF HOLE 882.3
7. THICKNESS OF OVERBURDEN 00.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 98.2 %
8. DEPTH DRILLED INTO ROCK 25.9 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.
9. TOTAL DEPTH OF HOLE 62.2 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Pea gravel aggregate and some chert fragments.			Concrete appeared to be satisfactory by visual observation with no loss recorded. Concrete was cored and discarded from 882.3' to 849.7'.
863.5	20.0					

LRH FORM 1836
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-8

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 882.3 | Hole No. G-8

PROJECT Dover Dam, Ohio | INSTALLATION HUNTINGTON DISTRICT | SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
849.7	34.7					Began Coring
				Rec 100%		
848.2	36.3		Top of Rock			
		LS	LIMESTONE: Dark gray to black, hard, thin bedded with laminated seams, fossiliferous.	Loss 0.0		
				Rec 100%	1	
843.9	40.9	SH	SHALE: Black, moderately hard. Badly broken zone from 839.9' to 839.7' 0.05' grout seam at 843.7'	Loss 0.0		
				Rec 98%		
841.0	44.0					

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-8

PROJECT	INSTALLATION	SHEET 3
Dover Dam, Ohio	HUNTINGTON DISTRICT	OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued)			
840.1	44.9					
		SLS	SILTSTONE: Sandy, dark gray into gray moderately hard to hard, sand content increases with depth. Partially weathered and broken zone from 840.3' to 839.5'	Loss 0.1 Rec 96% Loss 0.2 Rec 98% Loss 0.1 Rec 98% Loss 0.1	1 2	
823.9	62.2		Bottom of Hole			

LRH FORM 1836-A' MAY 04	PROJECT Dover Dam, Ohio	HOLE NO. G-8

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-9	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER: 870.7 -869.8
	16. DATE HOLE: STARTED 01-24-83; COMPLETED 01-28-83
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 882.3
8. DEPTH DRILLED INTO ROCK: 25.0 Feet	18. TOTAL CORE RECOVERY FOR BORING: 95.3 %
9. TOTAL DEPTH OF HOLE: 60.2 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Pea gravel aggregate.			Drilled through rebar 1/2" O.D. @ 881.4' Drilled through 0.5" metal plate at 876.7' Extremely hard to drill change from impregnated to diamond bit to penetrate, 30 minutes to drill through. Concrete cored and discorded from 882.3' to 853.5'.
863.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio — HOLE NO.: G-9

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-9
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
853.5	30.7			Rec 100%		Began Coring
						Started retaining core at elevation 850.1'
848.8	35.6		Top of Rock	Loss 0.0		
		LS	LIMESTONE: Dark gray, hard, fossilferous with laminated seams.	Rec 91%	1	
844.9	39.8	SH	SHALE: Black, moderately hard with some weathered and broken zones. Moderately broken from 844.4' to 843.4' Vertical fracture, open, rough, planar from 843.8' to 843.7' Moderately broken from 843.4' to 842.5' Moderately broken, thin bedded from 842.5' to 840.2'	Loss 0.5 Rec 94%		
841.0	44.0					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-9

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-9
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued)			
840.2	44.8		Evidence of mechanical spin at 841.9' Core diameter loss from 841.1' to 841.0'	Loss 0.3 Rec 96%	1	
		SLS	SILTSTONE: Sandy, dark gray into gray, moderately hard to hard, sandier with depth. Vertical fracture, open, planar rough from 835.7' to 835.4'	Loss 0.2 Rec 94% Loss 0.3 Rec 93% Loss 0.1 Rec 100% Loss 0.0 Rec 100% Loss 0.0	2	Brake 5' barrel. Used short barrel for the remaining part of the hole.
825.3	60.7		Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-9

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-10a	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olson	14. TOTAL NUMBER CORE BOXES 2
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER 863.3 - 862.9
	16. DATE HOLE: STARTED 02-07-83; COMPLETED 02-08-83
	17. ELEVATION TOP OF HOLE 886.3
7. THICKNESS OF OVERBURDEN 00.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 97.5 %
8. DEPTH DRILLED INTO ROCK 25.7 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.
9. TOTAL DEPTH OF HOLE 65.1 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Pea gravel aggregate and some chert fragments.			
		CON				Concrete cored and discarded from 886.3' to 850.7'.
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-10a

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-10a
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON				
850.7	37.9					Began Coring
849.4	39.3		Top of Rock	Rec 100%		
		LS	LIMESTONE: Dark gray to black, hard, fossiferous, with thin laminated seams. Moderately broken from 846.2' to 845.9' 56° fracture, open, planar, rough from 845.8' to 845.5'	Loss 0.0	1	
845.0	43.9			Rec 100%		

LRH FORM 1836-A
MAY 04

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-10a
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
		SH	SHALE: Black, moderately hard. Badly weathered zone from 836.3' to 836.0'. Badly broken zone from 834.8' to 833.8' Vertical fracture, open, planar, smooth from 844.4' to 844.2' Severely broken from 843.4' to 842.6' Thin bedded, moderately broken with multiple high angle fractures from 841.7' to 840.6'	Loss 0.0 Rec 100%		
840.7	48.5	SLS	SILTSTONE: Sandy, gray, moderately hard, sandier with depth. 55° fracture, open, planar, smooth from 832.5' to 832.1' Grout coated bedding plane at 829.3' Severely broken from 829.0' to 828.2'	Loss 0.0 Rec 96% Loss 0.2 Rec 98% Loss 0.1 Rec 91% Loss 0.3	1	
825.1	65.1		Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-10a

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-10b	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0 : UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olson	14. TOTAL NUMBER CORE BOXES: 3
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° West DEG. FROM VERT.	15. ELEVATION GROUND WATER: Unknown
	16. DATE HOLE: STARTED 4-7-83 : COMPLETED 4-13-83
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 886.3
8. DEPTH DRILLED INTO ROCK: 26.5 Feet	18. TOTAL CORE RECOVERY FOR BORING: 97.2 %
9. TOTAL DEPTH OF HOLE: 64.8 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	BOX c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Pea gravel aggregate and same chert			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 852.7'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio — HOLE NO. G-10b

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-10b
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
852.7	35.8					Began Coring
				Rec 100%		
850.3	38.3		Top of Rock			
		LS	LIMESTONE: Dark gray, hard, fossiliferous. 60° fracture, planar rough, grout coated from 846.9' to 846.5.		1	
				Loss 0.0		
				Rec 85%		
845.9	43.0					
845.0	44.0	SH	SHALE: Black, moderately hard, with some badly weathered zones.			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio HOLE NO. G-10b

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 882.3	Hole No. G-10b
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued) Fractured and badly broken from 846.3' to 844.0' Very soft and clayey from 845.7' to 845.3'	Loss 0.6 Rec 96%	1	
842.3	46.8	SLS	SILTSTONE: Sandy, dark gray, moderately hard, with some sandier zones and thin sandstone layers.	Loss 0.2 Rec 100%		
				Loss 0.0 Rec 100%	2	
				Loss 0.0 Rec 100%		
825.4	64.8			Loss 0.0	3	
			Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-10b

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olson	14. TOTAL NUMBER CORE BOXES 3
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER 873.1
	16. DATE HOLE: STARTED; COMPLETED
7. THICKNESS OF OVERBURDEN 00.0 Feet	17. ELEVATION TOP OF HOLE 886.3
8. DEPTH DRILLED INTO ROCK 28.7 Feet	18. TOTAL CORE RECOVERY FOR BORING 96.1 %
9. TOTAL DEPTH OF HOLE 65.4 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Pea gravel aggregate. (Average size pieces ranging from 8" to 9")			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 853.6'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-11

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-11
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
		CON	CONCRETE: (Concrete)			
853.6	34.8			Rec 100%		Began Coring
851.8	36.7	LS	Top of Rock LIMESTONE: Dark gray, hard, fossiliferous, with thin laminations.	Loss 0.0		
				Rec 96%		
847.6	41.2	SH	SHALE: Black, moderately hard with some slightly weathered zones. Angular fault from 843.7' to 843.4', no grout.			
845.0	44.0					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio HOLE NO. G-11

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-11
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued)	Loss 0.2 Rec 92%		
843.0	46.1	SLS	SILTSTONE: Sandy, gray, moderately hard. 3.7' Sandstone, medium grained from 833.6' to 829.9' 0.8' Sandstone, medium grained from 829.4' to 828.6' Grout coated bedding plane at 833.6 and 829.7'	Loss 0.4 Rec 96% Loss 0.2 Rec 98% Loss 0.1 Rec 94% Loss 0.3	1 2 3	
824.8	65.4		Bottom of Hole			

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam, Ohio | HOLE NO. G-11

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-12	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olsen	14. TOTAL NUMBER CORE BOXES 3
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER 873.1
	16. DATE HOLE: STARTED; COMPLETED
7. THICKNESS OF OVERBURDEN 00.0 Feet	17. ELEVATION TOP OF HOLE 886.3
8. DEPTH DRILLED INTO ROCK 30.8 Feet	18. TOTAL CORE RECOVERY FOR BORING 92.6 %
9. TOTAL DEPTH OF HOLE 65.8 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: With Pea gravel aggregate.			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 854.9'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-12

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-12
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
854.9	33.4					Began Coring
				Rec 100%		
853.4	35.0		Top of Rock			
		LS	LIMESTONE: Hard, dark gray, fossiliferous, with thin laminations. 70° fracture, open, planar, rough from 853.3' to 852.6' 55° fracture, open, planar, irregular, rough, moderately broken from 850.4' to 850.0'	Loss 0.0 Rec 98%		
848.9	39.8				1	
		SH	SHALE: Black, moderately hard. Broken and partially weathered zone from 847.5' to 846.5'. Thin grouted closed fractures from 844.3' to 844.1' and 848.1' to 847.5' 60° fracture open, planar, smooth from 848.1' to 847.9' and from 847.8' to 847.3' Moderately broken, thin bedded from 847.5' to 845.2'	Loss 0.1 Rec 89%		
845.0	44.0					

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-12
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued) Vertical fracture, open, planar smooth from 844.8' to 844.7' Grout coated bedding plane closed and irregular at 844.2', 844.15', and 844.06'	Loss 0.5 Rec 94%	1	
842.6	46.5		Mechanical spin loss at 843.3'			
		SLS	SILTSTONE: Sandy, dark gray, moderately hard, with some sandier zones.	Loss 0.3 Rec 94% Loss 0.3 Rec 96% Loss 0.2 Rec 80%	2	
826.2	64.0	SLS	SILTSTONE: Light gray, sandy, coarse grained.	Loss 1.0	3	
824.5	65.8		Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio — HOLE NO. G-12

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-13a	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 12-09-82; COMPLETED 12-09-82
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 886.3
8. DEPTH DRILLED INTO ROCK: 31.8 Feet	18. TOTAL CORE RECOVERY FOR BORING: 94.6 %
9. TOTAL DEPTH OF HOLE: 65.1 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: With pea gravel aggregate.			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 858.0'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio | HOLE NO.: G-13a

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-13a
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
858.0	30.1			Rec 100%		Began Coring
855.0	33.3		Top of Rock			
		LS	LIMESTONE: Black into dark gray, hard, fossiliferous, with thin laminations. Fault zones from 854.8 to 854.1 and 851.3 to 850.6	Loss 0.0 Rec 95%	1	
850.3	38.3	SH	SHALE: Black, moderately hard. Weathered and broken from 847.5 to 846.5 Thin grauted viens from 846.5 to 846.3	Loss 0.2 Rec 95% Loss 0.1 Rec 88%		
845.0	44.0				2	

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-13a

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-13a
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON_DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued)	Loss 0.6		
842.8	46.3	SLS	SILTSTONE: Sandy, gray, moderately hard, interlayered with some sandier zones. 55° fracture, open, rough, planar from 833.5' to 833.2'	Rec 94% Loss 0.3	2	
				Rec 96% Loss 0.2		
				Rec 90% Loss 0.5	3	
				Rec 100%		
825.5	64.7	SLS	SILTSTONE: Light gray, sandy, coarse grained.	Loss 0.0		
825.1	65.1		Bottom of Hole			

LRH FORM 1836-A MAY 04	PROJECT Dover Dam, Ohio	HOLE NO. G-13a

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-13b	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 3
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 35° W DEG. FROM VERT.	15. ELEVATION GROUND WATER: 873.1
	16. DATE HOLE: STARTED 3-29-83; COMPLETED 4-7-83
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 886.3
8. DEPTH DRILLED INTO ROCK: 31.4 Feet	18. TOTAL CORE RECOVERY FOR BORING: 84.8 %
9. TOTAL DEPTH OF HOLE: 64.4 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: With pea gravel and some chert.			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 857.3'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio | HOLE NO. G-13b

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-13b
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
857.3	30.9					Began Coring
855.3	33.0		Top of Rock	Rec 100%		
		LS	LIMESTONE: Dark gray to black, hard, fossiliferous. Multiple high angled, grout coated, rough, nonplanar fractured zone from 852.4' to 851.4'. 70° High angle, planar, rough grout coated fracture from 855.2' to 854.4'	Loss 0.0 Rec 100% Loss 0.0 Rec 100%	1	
850.7	37.9					
		SH	SHALE: Black, moderately hard. Broken zone with multiple 40°-60° fractures, rough and nonplanar. Badly broken and weathered zones from 847.3' to 846.1'.	Loss 0.0 Rec 81%		
846.1	42.8					
		SLS	SILTSTONE: Sandy, gray moderately hard, with some sandier zones.			
845.0	44.0				2	

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-13b

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-13b
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: (Continued)	Loss 0.8 Rec 91%		
840.5	48.7	SS	SANDSTONE: Gray, medium grained, moderately hard.	Loss 0.4		
838.8	50.5	SLS	SILTSTONE: Sandy, gray into dark gray, moderately hard, gradually becoming shaley (more fissle) with depth.	Rec 86% Loss 0.7 Rec 80% Loss 0.8 Rec 75%	2	
829.4	60.5	SLS	SILTSTONE: Gray, sandy, medium to coarse grained, moderately hard.	Loss 0.8 Rec 20% Loss 1.6	3	
825.8	64.4		Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-13b

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-14a	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 70° W DEC. FROM VERT.	15. ELEVATION GROUND WATER:
	16. DATE HOLE: STARTED 2-25-83; COMPLETED 3-2-83
7. THICKNESS OF OVERBURDEN: 00.0 Feet	17. ELEVATION TOP OF HOLE: 886.3
8. DEPTH DRILLED INTO ROCK: 13.5 Feet	18. TOTAL CORE RECOVERY FOR BORING: 90.8 %
9. TOTAL DEPTH OF HOLE: 65.1 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: Pea gravel aggreagate and Chert.			
						Concrete appeared to be satisfactory by visual observation with no loss recorded.
						Concrete cored and discarded from 886.3' to 839.4'.
		CON				
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio | HOLE NO.: G-14a

LRH Form 1836.dgn 8/21/2006 11:14:08 AM

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-14o
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: (Continued)			
		CON				
845.0	44.0					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio HOLE NO. G-14o

LRH Form 1836.dgn 8/21/2006 11:14:49 AM

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-14a
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON_DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
839.4	49.9					Began Coring
837.8	51.6		Top of Rock	Rec 78%		
836.9	52.6	LS	LIMESTONE: Dark gray to black, hard, fossiliferous.			Loss occumulotive. Majority of loss probably in Concrete Rock bond area.
830.2	59.7	SH	SHALE: Sandy, dark gray into gray, moderately hard, with some sandier zones. Grouted fracture from 836.2' to 835.9', possible fault. More Shaly from 832.3' to 830.2'.	Loss 1.1 Rec 96% Loss 0.2	1	
825.1	65.1	SLS	SILTSTONE: Gray, moderately hard, sandy, medium to coarse grained. Medium bedded with grout coated planes from 827.9' to 827.3'.	Rec 98% Loss 0.1	2	
			Bottom of Hole			

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam, Ohio | HOLE NO. G-14a

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT NX
2. LOCATION (Coordinates or Station) Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
3. DRILLING AGENCY Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL Unknown
4. HOLE NO. (As shown on drawing title and file number) G-14b	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER Kenny Olsen	14. TOTAL NUMBER CORE BOXES 2
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 3-11-83; COMPLETED 3-17-83
7. THICKNESS OF OVERBURDEN 00.0 Feet	17. ELEVATION TOP OF HOLE 886.3
8. DEPTH DRILLED INTO ROCK 13.4 Feet	18. TOTAL CORE RECOVERY FOR BORING 95.5 %
9. TOTAL DEPTH OF HOLE 65.2 Feet	19. NAME OF INSPECTOR Jerry Ballard Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Pea gravel aggregate and Chert.			Concrete appeared to be satisfactory by visual observation with no loss recorded. Concrete cored and discarded from 886.3' to 839.7'.
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT Dover Dam, Ohio — HOLE NO. G-14b

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-14b
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
			CONCRETE: (Continued)			
		CON				
845.0	44.0					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-14b

LRH Form 1836.dgn 8/21/2006 11:16:36 AM

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 886.3 | Hole No. G-14b

PROJECT Dover Dam, Ohio | INSTALLATION HUNTINGTON DISTRICT | SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: (Continued)			
839.7	49.6			Rec 96%		Began Coring
836.7	51.8		Top of Rock			
		SLS	SILTSTONE: Sandy, dark gray into gray, moderately hard, with some sandier zones. Broken zone from 837.2' to 836.9'.	Loss 0.2 Rec 94%	1	
830.9	59.0	SLS	SILTSTONE: Gray, moderately hard, sandy, medium to coarse grained. Dark gray Shale layer from 830.5' to 829.9' and from 829.4' to 829.3'.	Loss 0.3 Rec 96%		
				Loss 0.2 Rec 100% Loss 0.0	2	
825.0	65.2		Bottom of Hole			

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam, Ohio | HOLE NO. G-14b

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 3 SHEETS

1. PROJECT: Dover Dam	10. SIZE AND TYPE OF BIT: NX
2. LOCATION (Coordinates or Station): Ohio	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 1929
3. DRILLING AGENCY: Unknown	12. MANUFACTURER'S DESIGNATION OF DRILL: Unknown
4. HOLE NO. (As shown on drawing title and file number): G-15	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
5. NAME OF DRILLER: Kenny Olsen	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 20° S 70° W DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 3-3-83; COMPLETED 3-10-83
	17. ELEVATION TOP OF HOLE: 886.3
7. THICKNESS OF OVERBURDEN: 00.0 Feet	18. TOTAL CORE RECOVERY FOR BORING: 96.4 %
8. DEPTH DRILLED INTO ROCK: 19.6 Feet	19. NAME OF INSPECTOR: Jerry Ballard Jr.
9. TOTAL DEPTH OF HOLE: 64.8 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e.	BOX OR SAMPLE NO. f.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Pea gravel aggreagate and Chert.			Concrete appeared to be satisfactory by visual observation with no loss recorded. Concrete cored and discarded from 886.3' to 843.8'.
867.5	20.0					

LRH FORM 1836
MAY 04

PROJECT: Dover Dam, Ohio — HOLE NO. G-15

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3		Hole No. G-15
PROJECT Dover Dam, Ohio		INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: (Continued)			
		CON				
845.0	44.0					

LRH FORM 1836-A
MAY 04

PROJECT	HOLE NO.
Dover Dam, Ohio	G-15

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.3	Hole No. G-15
PROJECT Dover Dam, Ohio	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
			CONCRETE: (Continued)			
843.8	45.2					Began Coring
		CON		Rec 98%		
839.7	49.6		Top of Rock			
		SLS	SILTSTONE: Sandy, dark gray, moderately hard, with some sandier zones. Moderately broken bedding planes with breaks 0.03' to 0.1' average spacing between 839.1' to 836.3' Moderately broken with bedding planes spaced at 0.02' to 0.2' from 834.3' to 833.4' Severely broken from 833.4' to 831.8'	Loss 0.1 Rec 100% Loss 0.0 Rec 91%	1	
831.8	58.0					
		SLS	SILTSTONE: Gray, moderately hard, sandy, medium to coarse grained. SHALE, silty, dark gray, thin bedded, with thin light gray Sandstone stringers throughout from 829.4' to 829.1'	Loss 0.4 Rec 96%	2	
825.4	64.8			Loss 0.2		
			Bottom of Hole			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam, Ohio | HOLE NO. G-15

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326733.86 E 2301857.81	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 3; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 21
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 919.5
	16. DATE HOLE: STARTED 6/24/04; COMPLETED 6/24/04
7. THICKNESS OF OVERBURDEN 4.2 Feet	17. ELEVATION TOP OF HOLE 932.21 Feet
8. DEPTH DRILLED INTO ROCK 69.1 Feet	18. TOTAL CORE RECOVERY FOR BORING 98.8%
9. TOTAL DEPTH OF HOLE 73.3 Feet	19. NAME OF INSPECTOR STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
931.8	0.4	OL	ORGANIC CLAY WITH SAND (OL), br. and gr., low pl., ve. mst., m. to f. sand w/tr. rt. and wood frags.	52.1						WH
		GC	CLAYEY GRAVEL WITH SAND (GC), gr. and br., low pl., mst., ang. to rou. gravel, c. to f. sand	8.2	32	22				3, 4, 4
929.2	3.0			6.3						3, 2
928.0	4.2	CL	LEAN CLAY (CL), gr., low pl., dry, w/wd. silty SH							25, 52, 50/0.2

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
921.5	10.7	SH	SHALE: Soft to mod. hard, gray, silty to sandy. Slight weathering from 928.0 to 926.0. Bedding plane breaks every 0.2' from 928.0 to 924.1. Increasingly silty with depth from 925.6 to 921.5.	REC 79% RQD 0% L 0.8 REC 100% RQD 93%	1 2	
		SS	SANDSTONE: Med. to coarse grained, light gray, micaceous, hard, occassional shale stringers, crosbedded. Gray shale zone from 920.9 to 920.1. 45° Fracture, iron stained from 920.9 to 920.7. Moderate weathering from 920.9 to 918.8. Broken zone with severe weathering and soft from 920.4 to 920.1. Iron staining from 910.9 to 898.4. 55° Iron stained fracture from 910.4 to 910.0. Horizontal, iron stained fracture at 902.1, 902.0 Near vertical fracture, iron stained from 902.0 to 901.6. Vertical fracture from 885.3 to 884.3. Coal stringers from 884.2 to 883.2.	L 0.0 REC 100% RQD 100% L 0.0 REC 100%	3 4 5	▽ 6/24/04

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-1

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 932.21		Hole No. C-04-1
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT		SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				RQD 92%	5	
				L 0.0		
				REC 100%	6	
				RQD 100%	7	
				L 0.0		
				REC 100%	8	
				RQD 90%		
		SS				
				L 0.0		
				REC 100%	9	
				RQD 100%	10	
				L 0.0		
				REC 100%	11	
				RQD 100%		
				L 0.0	12	
	44			REC 100%		

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 932.21	Hole No. C-04-1
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
878.0	54.2	SS		RQD 80% L 0.0 REC 100% RQD 91% L 0.0 REC 100%	12 13 14 15	
870.0	62.2	SH	SHALE: Dark gray, soft, occassional slickensides, carbonaceous, occassional siderite nadules. Clay seam, plastic, damp, dark gray and slight sulfer smell from 878.0 to 877.9. Broken every 0.1'-0.05' from 878.0 to 874.0. Calcite stringers from 874.6 to 874.5. Siderite nodules from 873.3 to 873.0. Calcareous from 872.8 to 870.0.	RQD 18% L 0.0 REC 100% RQD 70%	16 17	
867.9	64.3	LS	LIMESTONE: Dark gray, hard, crystalline grained, fossiliferous.	L 0.0 REC 100%	18	
865.5	66.7	C	COAL: Black, soft, blocky, vitreous. Bone coal, black, hard from 866.8 to 865.5.	RQD 54%		
	68	SH	SHALE: Gray, silty to sandy, mod. hard, occassional sandstone stringers.	L 0.0	19	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 932.21	Hole No. C-04-1
PROJECT Dover Dam -	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			SHALE Cont. Occossional siderite nodules from 862.0 to 861.0.	REC 100%	19	
		SH		RQD 100%	20	
858.9	73.3			L 0.0	21	
			BOTTOM OF HOLE @ 858.9			
	92					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-1

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326760.03 E 2301884.66	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 20
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 922.2
	16. DATE HOLE: STARTED 6/28/04; COMPLETED 6/29/04
7. THICKNESS OF OVERBURDEN 4.9 Feet	17. ELEVATION TOP OF HOLE 933.81 Feet
8. DEPTH DRILLED INTO ROCK 68.7 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 73.6 Feet	19. NAME OF INSPECTOR STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
933.0	0.8	SC-SM	SILTY CLAYEY SAND (SC-SM), gr., low pl., mst., f. sand w/tr. org. and animal discard odor							1
										2
		GC	CLAYEY GRAVEL WITH SAND (GC), gr., m. pl., mst., subong. to rou. gravel, f. sand	7.3	32	21				3
										5
										3
										4
			low pl. @ El. 930.8 - El. 929.7	8.8						3
929.7	4.1									3

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	BLOWS
928.9	4.9	CL	LEAN CLAY (CL), gr., low pl., dry w/wd. silty SH				25
							50/0.4
927.4	6.4	SH	SHALE: Gray, soft, laminated. Vertical fracture from 928.8 to 927.4.	REC 100% RQD 17%	1		
926.6	7.2	SS	SANDSTONE: Gray, mod. hard, med. grained, micaceous. 60° Fracture from 927.4 to 926.8.	L 0.0			
921.1	12.7	SH	SHALE: Gray, soft to mod. hard, laminated, silty to sandy. 45° Fracture at 925.1. Vertical fracture from 922.2 to 922.0. Vertical fracture from 921.7 to 921.1.	REC 100% RQD 61%	2	▽ 6/29/04	
		SS	SANDSTONE: Light gray, hard, med. grained, crossbedded, thick beds, micaceous iron stained. Vertical fracture from 904.3 to 902.7. 70° Fracture from 890.2 to 888.9.	L 0.0 REC 100% RQD 100%	3		
				L 0.0	4		
				REC 100%	5		

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-2

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.81	Hole No. C-04-2
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				RQD 100%	5	
				L 0.0		
				REC 100%	6	
				RQD 100%	7	
				L 0.0		
				REC 100%		
		SS		RQD 68%	8	
				L 0.0		
				REC 100%	9	
				RQD 98%		
				L 0.0	10	
				REC 100%		
				RQD 100%	11	
	44			L 0.0		

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-2

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.81	Hole No. C-04-2
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				REC 100%		
				RQD 74%	12	
				L 0.0		
		SS		REC 100%	13	
				RQD 100%	14	
				L 0.0		
878.9	54.9			REC 100%		
			SHALE: Dark gray, mod. hard, laminated, scattered siderite nodules, numerous slickensided fractures, efferevescent in last 0.2'. 45° Fracture at 875.7.	RQD 26%	15	
		SH		L 0.0		
				REC 100%	16	
871.6	62.2			RQD 24%		
			LIMESTONE: Gray, very hard, fine to med. crystalline grained, fossiliferous.		17	
		LS		L 0.0		
867.7	66.1			REC 100%		
		C	COAL: Black, mod. hard, vitreous luster.	RQD 60%	18	
865.9	67.9	SH				

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.81	Hole No. C-04-2
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			SHALE Cont.	L 0.0		
			Dark gray to black, mod. hard, carbonaceous, laminated, silty.	REC 100%		
			Silty from 865.9 to 865.3.		19	
			Coal stringers from 865.0 to 864.0.			
		SH		RQD 97%		
					20	
860.1	73.7			L 0.0		
			BOTTOM OF HOLE @ 860.1			
	92					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam
HOLE NO. C-04-2

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS
1. PROJECT Dover Dam		10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW	
2. LOCATION (Coordinates or Station) N 326644.53 E 2301866.04		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29	
3. DRILLING AGENCY HC NUTTING		12. MANUFACTURER'S DESIGNATION OF DRILL CME 45	
4. HOLE NO. (As shown on drawing title and file number) C-04-3		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED 0	
5. NAME OF DRILLER BRAGG		14. TOTAL NUMBER CORE BOXES 22	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEC. FROM VERT.		15. ELEVATION GROUND WATER 891.4	
7. THICKNESS OF OVERBURDEN 17.5 Feet		16. DATE HOLE: STARTED 5/17/04; COMPLETED 5/19/04	
8. DEPTH DRILLED INTO ROCK 74.5 Feet		17. ELEVATION TOP OF HOLE 933.65 Feet	
9. TOTAL DEPTH OF HOLE 92.0 Feet		18. TOTAL CORE RECOVERY FOR BORING 100%	
		19. NAME OF INSPECTOR STEWART	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
933.2	0.5	SW	WELL GRADED SAND WITH GRAVEL (SW), br. and bk., dry, ang. to rou. gravel, c. to f. sand w/asphalt							29
930.7	3.0	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand	6.4						11, 5, 9, 3, 8
927.7	6.0	SW-SM	WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand	5.0			40	48	12	12, 9, 9, 5, 6, 5
921.7	12.0	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand	5.9 5.6						6, 13, 6, 6, 9, 15, 8, 10, 10, 8, 8, 6
918.7	15.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. and br., m. pl., mst., subang. gravel, f. sand w/SS and SH frags.	15.8	34	20	20	19	61	5, 3, 4, 2, 3, 3
917.2	16.5	CL	SANDY LEAN CLAY (CL), gr. br., low pl., mst., f. sand w/tr. SH and SS frags.	13.8 4.6						5, 4, 3
916.2	17.5	SM	SILTY SAND (SM), lt. br., non pl., dry, f. sand w/wd. SS							23, 50

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
		SS	SANDSTONE: Light brown/gray, hard, med. grained, micaceous, crossbedded, numerous fractures with number of fractures decreasing with depth. Vertical fracture from 906.8 906.5.	REC 100% RQD 0% 0.0 REC 100% RQD 0%	1	

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-3

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.65	Hole No. C-04-3
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			SANDSTONE Cont.	RQD 0%	1	
			Several 45° fractures from 906.5 to 905.8.		2	
			30° Fracture at 905.2 and 898.2.			
			60° Fracture from 904.2 to 903.8.			
			35° Fracture at 901.4 and 901.2.	L 0.0		
			Open vertical fracture from 879.9 to 877.5.	REC 100%		
				RQD 0%	3	
				L 0.0		
				REC 100%	4	
				RQD 47%		
		SS			5	
				L 0.0		
				REC 100%		
				RQD 88%	6	
				L 0.0		
				REC 100%	7	
				RQD 90%		
					8	▽ 5/19/04
	44			L 0.0		

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-3

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.65	Hole No. C-04-3
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS		REC 100% RQD 90% L 0.0	9	
				REC 100% RQD 92% L 0.0	10	
					11	
877.5	56.2			REC 100%		
		SH	SHALE: Dark gray to black, mod. hard, numberous siderite nodules throughout, laminated.	RQD 0% L 0.0	12	
872.7	61.0			REC 100%	13	
		LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded, fossiliferous. Open vertical fracture from 872.7 to 870.4. Vertical fracture from 870.4 to 868.7.	RQD 28% L 0.0	14	
869.0	64.7			REC 100%		
		C	COAL: Black, pyritic, vitreous.			
867.4	66.3					
	68	SH	SHALE: Gray, silty, mod. hard, laminated 1/3' thick with some being carbonaceous, sandy in zones. 45° Fracture at 858.3.	RQD 50%	15	

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam — HOLE NO. C-04-3

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.65	Hole No. C-04-3
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
852.2	81.5	SH	SHALE Cont. 30° Fracture at 856.5 and 856.3. 70° Fracture at 855.2. Several coal stringers and one coal lamination 1/3' thick from 863.3 to 863.0. Zone of fractures from 856.6 to 853.3.	L 0.0 REC 100% RQD 88% L 0.0' REC 100% RQD 30% L 0.0 REC 100% RQD 66%	15 16 17 18 19	
848.3	85.4	LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded, fossiliferous.	L 0.0 REC 100%	20	
844.1	89.6	SH	SHALE: Dark gray to black, mod. hard, silty, fossiliferous in upper part, laminated, carbonaceous. 40° Fracture with slickensided surface at 845.5 and 845.2.	RQD 85% L 0.0 REC 100% RQD 88%	21	
841.7	92	SS	SANDSTONE: Gray, mod. hard, very fine grained, shaley.		22	
			BOTTOM OF HOLE @ 841.7	L 0.0		

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam — HOLE NO. C-04-3

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT: Dover Dam
2. LOCATION (Coordinates or Station): N 326713.76 E 2301955.00
3. DRILLING AGENCY: HC NUTTING
4. HOLE NO. (As shown on drawing title and file number): C-04-4
5. NAME OF DRILLER: BRAGG
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 28.4 Feet
8. DEPTH DRILLED INTO ROCK: 72.7 Feet
9. TOTAL DEPTH OF HOLE: 101.1 Feet
10. SIZE AND TYPE OF BIT: 4" CORE AND 3" HOLLOW
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): NGVD 29
12. MANUFACTURER'S DESIGNATION OF DRILL: CME 45
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 12 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 22
15. ELEVATION GROUND WATER: 899.9
16. DATE HOLE: STARTED 5/10/04 : COMPLETED 5/11/04
17. ELEVATION TOP OF HOLE: 933.79 Feet
18. TOTAL CORE RECOVERY FOR BORING: 98.5%
19. NAME OF INSPECTOR: STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
		GP	POORLY GRADED GRAVEL WITH SAND (GP), br., dry, subang. to ang. gravel, c. to f. sand w/asphalt frags. mst., ang. to rou. gravel w/alluvium, flint and SS frags. @ El. 933.2-El. 930.7							100
				5.9						28
										47
										15
										21
930.8	3.0									18
		SP-SM	POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand w/alluvium, flint and SS frags.	4.4			40	50	10	6
										18
										21
										8
										14
										12
				4.8						9
										18
										14
										6
										11
										9
				5.4						7
										7
										15
										12
										9
										9
				4.9						8
										11
										9
										4
										15
										9
				4.8			43	49	8	5
										5
										7
										4
										4
915.8	18.0									5
		SP	POORLY GRADED SAND WITH GRAVEL (SP), br.,mst., ang. to rou. gravel, c. to f. sand w/ alluvium, flint and SS frags.	4.5						5
										5
										4
913.8	20.0									3

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.79	Hole No. C-04-4
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
912.8	21.0	SP	POORLY GRADED SAND WITH GRAVEL (SP), br., mst., ang. to rou. gravel, c. to f. sand w/ alluvium, flint and SS frags.	4.5						3, 2
		GP	POORLY GRADED GRAVEL WITH SAND (GP), br. and whi., ve. mst. to mst., ang. to rou. gravel, c. to f. sand w/alluvium and SS frags.	6.1						3, 4, 5
										4, 3, 3
			br. @ El. 909.7-El. 906.7	7.3						3, 4, 3
										6, 4, 4
906.8	27.0									
		GP-GC	POORLY GRADED GRAVEL WITH SAND AND SILTY CLAY (GP-GC), br., low pl., mst., ang. to rou. gravel, c. to f. sand w/SS and conglomerate frags. and alluvium	9.1 / 6.5						7
905.8	28.0	SM	SILTY SAND WITH GRAVEL (SM), gr., non pl., dry, ang. to rou. gravel, c. to f. sand w/SS frags. and alluvium							11
905.4	28.4									52/0.4

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS	SANDSTONE: Light gray and light brown, med. to coarse, mod. hard, micaceous, weathered, somewhat friable, iron stained throughout.	REC 100% RQD 0% L 0.0		
			Numerous fractures from 905.4 to 901.5.	REC 47%	1	
			50° Fracture at 900.6 and from 885.0 to 884.4.	RQD 0%		
			Shaley and fractured from 896.8 to 896.5.	L 1.1		
			Vertical open fracture along carbonaceous lamination from 892.5 to 890.6.	REC 100%		
			Vertical surface crack from 889.5 to 888.9.			
			45° Fracture from 886.1 to 885.7.	RQD 0%	2	▽ 5/11/04
			Vertical fracture from 885.0 to 883.5 and 905.1 to 904.7.	L 0.0		
			Numerous soft shale lenses and clayey stringers from 882.8 to 882.2.	REC 100%		
				RQD 56%	3	
				L 0.0		
				REC 100%	4	
				RQD 62%	5	
	44					

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-4

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.79	Hole No. C-04-4
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS		L 0.0 REC 100% RQD 36%	5 6	
880.8	53.0			L 0.0 REC 100% RQD 38%	7	
		SH	SHALE: Dark gray, mod. hard, laminated, weathered, few slickensided fractures, few siderite nodules throughout. 20° Slickensided fracture at 879.9. Vertical fracture from 879.0 to 878.6 and 876.6 to 876.1. Slightly effervescent from 876.8 to 874.7.	L 0.0 REC 100% RQD 0%	8 9	
874.7	59.1	LS	LIMESTONE: Gray, hard, fossiliferous. Vertical healed fracture from 874.7 to 873.3.	L 0.0 REC 100%	10	
872.3	61.5	C	COAL: Black, vitreous, pyritic.			
871.0	62.8	SH	SHALE: Light gray, mod. hard, carbonaceous zones, thin bedded. 50° Fracture at 870.3. 45° Fracture 868.8. Dark gray, silty to sandy from 866.7 to 848.6. Vertical fracture from 868.3 to 868.0 and 864.8 to 863.9. 60° Fracture from 861.0 to 860.5. Effervescent from 864.4 to 848.7.	RQD 20% L 0.0 REC 100% RQD 76%	11 12	
	68					

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.79	Hole No. C-04-4
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE Cont. 80° Fracture from 858.8 to 853.8.	L 0.0 REC 100% RQD 72% L 0.0 REC 100% RQD 78% L 0.0 REC 100% RQD 88% L 0.0	12 13 14 15 16 17	
848.6	85.2					
		LS	LIMESTONE: Dark gray, hard, thick bedded, fossiliferous. Vertical fracture zone from 845.0 to 843.9.	REC 100% RQD 72% L 0.0	18	
843.6	90.2					
	92	SH	SHALE: Dark gray to black, mod. hard, carbonaceous and calcareous and fossiliferous near top, laminated. 45° Fracture 838.3.	REC 100%	19	

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-4

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.79	Hole No. C-04-4
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 5 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
838.1	95.7	SH	SHALE Cont. Near vertical fracture from 842.5 to 841.3.	RQD 31% L 0.0	19	
832.7	101.1	SLS	SILTSTONE: Gray, mod. hard, thin bedded, shaley. Sandy zone from 834.6 to 833.6.	REC 100% RQD 87% L 0.0	20 21	
				REC 100% RQD 100% L 0.0	22	
	116		BOTTOM OF HOLE @ 832.7.			

DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 2 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326540.28 E 2301875.50	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-5	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED 15 : UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 0
	15. ELEVATION GROUND WATER 878.0
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	16. DATE HOLE : STARTED 4/28/04 : COMPLETED 4/28/04
	17. ELEVATION TOP OF HOLE 901.69 Feet
7. THICKNESS OF OVERBURDEN 35.5 Feet	18. TOTAL CORE RECOVERY FOR BORING N/A %
8. DEPTH DRILLED INTO ROCK 0 Feet	19. NAME OF INSPECTOR STEWART
9. TOTAL DEPTH OF HOLE 35.5 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
901.3	0.3	GM	SILTY GRAVEL WITH SAND (GM), bk., non pl., mst. w/orgs. and animal discard odor	30.9						2
		GP-GM	POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM), br., non pl., mst., subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	9.8						3, 5, 4, 5, 4
895.6	6.0		ang. to rou. gravel @ El. 898.6-El. 895.6	5.3			49	42	9	1, 7, 9, 4, 8, 15
892.6	9.0	GP	POORLY GRADED GRAVEL WITH SAND (GP), br., mst., ang. to rou. gravel, c. to f. sand w/SS and alluvium	7.3						8, 14, 16, 6, 14, 13
889.6	12.0	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., ve. mst., subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	12.2			31	50	19	6, 8, 8, 5, 5, 7
886.6	15.0	GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), br., low pl., ve. mst., subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	9.4						2, 1, 2, 5, 6, 5
		SM	SILTY SAND WITH GRAVEL (SM), br., low to non pl., ve. mst., subang. to rou. gravel, c. to f. sand w/SS frags, alluvium, and flint	11.1						7, 12, 6
881.9	19.7		ang. to rou. gravel @ El. 884.8-El. 881.9	13.1			18	53	29	2, 4, 8, 4, 2, 3
881.6	20.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. pl., ve. mst., subang. to rou. gravel, f. sand w/ tr. wood frags. and natural gas odor	20.5			29	20	51	1

LRH FORM 1836 MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-5

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 901.69	Hole No. C-04-5
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
879.1	22.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. pl., ve. mst., subang. to rou. gravel, f. sand w/tr. wood frags. and natural gas odor	20.5			29	20	51	2 3 3 6 4
876.1	25.5	CL	GRAVELLY LEAN CLAY (CL), gr., m. pl., ve. mst., subang. to ang. gravel w/tr. wood frags. and natural gas odor	31.1	41	23	▽ 4/28/04			1 5 3 2 4 4
873.1	28.5	CL	LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel	20.2						1 3 7 4 8 11
870.6	31.0	CL	SANDY LEAN CLAY (CL), br., m. pl., ve. mst., f. sand	18.4	27	15				2 5 8 3 4
868.9	32.7	SC-SM	SILTY CLAYEY SAND (SC-SM), gr. and br., low pl., ve. mst., f. sand	20.0			4	53	43	5 10 9 10
867.1	34.5	CL	LEAN CLAY WITH SAND (CL), gr., low pl., mst., f. sand w/tr. SS frags. and mottled	13.3						5 11 45
866.1	35.5	CL	LEAN CLAY (CL), m. to low pl., mst. w/wd. shale and mottled	11.3						11 50
	44		BOTTOM OF HOLE							

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-5

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326575.10 E 2301911.35	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-5A	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 15; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 20
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 871.5
	16. DATE HOLE: STARTED 5/7/04; COMPLETED 5/9/04
7. THICKNESS OF OVERBURDEN 35.2 Feet	17. ELEVATION TOP OF HOLE 902.03 Feet
8. DEPTH DRILLED INTO ROCK 70.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 105.2 Feet	19. NAME OF INSPECTOR STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
901.7	0.3	ML	GRAVELLY SILT WITH SAND (ML), dk. br., non pl., mst., subang. gravel, f. sand w/org. and animal discord	28.1						3, 5
899.0	3.0	GP	POORLY GRADED GRAVEL WITH SAND (GP), br., mst., ang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	7.6						8, 6, 14, 11
896.0	6.0	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., mst., subang. to ang. gravel, c. to f. sand w/SS and LS frags and alluvium	6.7			38	46	16	4, 15, 17, 14, 20, 17
893.0	9.0	SP-SM	POORLY GRADED SAND WITH GRAVEL AND SILT (SP-SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand w/SS and LS frags. and alluvium	5.6			43	46	11	12, 16, 15, 10, 23, 19
890.0	12.0	GP	POORLY GRADED GRAVEL WITH SAND (GP), br., ve. mst., ang. to rou. gravel, c. to f. sand w/SS and LS frags. and alluvium	7.2						11, 10, 7, 4, 2, 1
887.0	15.0	GP-GM	POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM), br., non pl., wet to ve. mst., subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	12.4						3, 5, 5, 5, 9, 9
882.7	19.3	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., wet, subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	11.9			21	65	14	4, 9, 12, 7, 10, 8
			low pl. @ El. 884.0-El. 882.7	13.0						5, 3
882.0	20.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. pl., ve. mst., subang. to rou. gravel, c. to f. sand	20.4						4, 4

LRH FORM 1836 MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-5A

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.03	Hole No. C-04-5A
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
			GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. pl., ve. mst., subang. to rou. gravel, c. to f. sand	20.4						4 14
			mst., subang. gravel w/f. sand @ El. 881.0-El. 878.0	20.7	35	23				3 3 5 4 9 5
878.0	24.0									
		CL	LEAN CLAY WITH SAND (CL), gr., m. pl., mst., f. sand	18.1	37	22				WH 3 4 3 6 9
				16.2						5 9 13 4 7 9
872.0	30.0									
			SANDY LEAN CLAY WITH GRAVEL (CL), br., m. pl., mst., subang. gravel, f. sand	16.2	38	23	▽ 5/9/04			5 8 12 9 8 9
869.3	32.7									
		CL-ML	SILTY CLAY (CL-ML), gr. and br., low pl., mst. w/wd. silty SH and SH frags.	12.7 6.4						5 8 17
			gr., dry @ El. 867.5-El. 866.8	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g				14 50/.2
866.8	35.2									
		SH	SHALE: Gray, silty, mod. hard, laminated to very thin bedded, weathered to 862.2, effervescent starting at 862.2. 45° Fracture at 862.2, and from 856.1 to 855.6. Vertical fracture from 860.3 to 860.2. 20° Fracture at 859.5.	REC 100% RQD 0% L 0.0	1					
				REC 100% RQD 24% L 0.0	2 3					
	44									

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-5A

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.03	Hole No. C-04-5A
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH		REC 100%	3	
				RQD 38%	4	
				L 0.0		
851.6	50.4			REC 100%		
		LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded, fossiliferous.	RQD 90%	5	
847.6	54.4			L 0.0		
		SH	SHALE: Dark gray, mod. hard, carbonaceous, fossiliferous, calcareous in upper part, laminated.	REC 100%	6	
				RQD 45%	7	
843.3	58.7			L 0.0		
		SS	SANDSTONE: Gray, mod. hard, very fine grained, shaley, laminated. Light gray with brown and maroon crossbeds, hard from 837.3 to 835.8. 20° Fracture at 834.5.	REC 100%		
				RQD 93%	8	
				L 0.0		
				REC 100%	9	
				RQD 94%		
	68				10	

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.03	Hole No. C-04-5A
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L 0.0		
				REC 100%	10	
				RQD 98%	11	
		SS		L 0.0		
				REC 100%	13	
				RQD 98%		
823.3	78.7			L 0.0		
		SLS	SILTSTONE: Gray, mod. hard, shaley, laminated. Sandy zone from 822.2 to 821.7, 821.0 to 820.9, 819.8 to 819.3 and 817.9 to 817.7.	REC 100%	13	
				RQD 90%	14	
				L 0.0		
817.5	84.5			REC 100%		
		SS	SANDSTONE: Light gray, hard, med. grained, occassional silty shale, carbonaceous laminations, crossbedded, micaceous. Near vertical fracture from 811.1 to 810.7. 25° Fracture at 807.5. Siltstone zone, dark gray from 807.1 to 804.8. 45° Fracture at 805.0. Occassional coal stringers in last 3.0'.	RQD 92%	15	
				L 0.0		
				REC 100%	16	
				RQD 88%		
	92				17	

LRH FORM 1836-A
MAY 04

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.03	Hole No. C-04-5A

PROJECT	INSTALLATION	SHEET 5
Dover Dam	HUNTINGTON DISTRICT	OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
				L 0.0 REC 100%	17	
				RQD 80%	18	
		SS		L 0.0 REC 100%		
				RQD 78%	19	
				L 0.0 REC 100% RQD 67%	20	
796.8	105.2			L 0.0		
			BOTTOM OF HOLE @ 796.8			
	116					

LRH FORM 1836-A
MAY 04

PROJECT	HOLE NO.
Dover Dam	C-04-5A

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326580.98 E 2301918.29	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-6	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 16; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 21
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 871.8
	16. DATE HOLE: STARTED 4/28/04; COMPLETED 5/5/04
7. THICKNESS OF OVERBURDEN 35.0 Feet	17. ELEVATION TOP OF HOLE 902.09 Feet
8. DEPTH DRILLED INTO ROCK 70.5 Feet	18. TOTAL CORE RECOVERY FOR BORING 99.3%
9. TOTAL DEPTH OF HOLE 105.5 Feet	19. NAME OF INSPECTOR STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
901.8	0.3	CL-ML	GRAVELLY SILTY CLAY WITH SAND (CL-ML), dk. br., low pl., mst., ang. gravel, f. sand w/tr. org.	28.6						3 5 11
899.1	3.0	GP-GM	POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM), br., non pl., mst., subang. gravel, c. to f. sand w/SS frags.	8.5						7 11 16
896.1	6.0	SM	SILTY SAND WITH GRAVEL (SM), br., non pl., mst., ang. to rou. gravel, c. to f. sand	7.2			36	50	14	5 11 11 / 10 21 19
890.1	12.0	GM	SILTY GRAVEL WITH SAND (GM), br., non pl., mst., ang. to rou. gravel, c. to f. sand	8.0 / 7.5						7 13 16 / 10 15 11 / 8 8 3 / 2 4 7
882.1	20.0	SM	SILTY SAND WITH GRAVEL (SM), br., low to non pl., mst., subang. gravel, c. to f. sand ve. mst. @ El. 887.0-El. 879.7	10.4 / 11.9 / 10.0			21 / / 19	62 / / 65	17 / / 16	4 5 11 / 5 9 10 / 7 13 12 / 9 8 8 / 8 13 14 / 7

LRH FORM 1836 MAY 04

PROJECT Dover Dam | HOLE NO. C-04-6

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.09	Hole No. C-04-6
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
		SM	SILTY SAND WITH GRAVEL (SM), br., low to non pl., mst., subang. gravel, c. to f. sand	10.0			19	65	16	7, 6
				12.0						4, 6, 5
879.8	22.3									
		CL	GRAVELLY LEAN CLAY (CL), gr., m. pl., mst., subang. gravel w/tr. org. and chert	23.4						2, 3, 16
878.1	24.0									
		SP-SM	POORLY GRADED SAND WITH GRAVEL AND SILT (SP-SM), lt. br., non pl., mst., subang. gravel, f. sand w/wd. SS	8.9						22, 8, 6
876.6	25.5									
		CL	SANDY LEAN CLAY (CL), gr., m. pl., f. sand w/tr. SS frags.	17.3	36	21				5, 8, 9, 4, 7, 12
873.6	28.5									
		CL	SANDY LEAN CLAY (CL), gr., m. pl., mst., f. sanc	15.9	35	21	▽ 5/4/04			3, 6, 9, 4, 7, 10
870.6	31.5									
			SANDY LEAN CLAY WITH GRAVEL (CL), gr., m. to low pl., mst., subang. gravel, f. sand	14.9						4, 7, 10
869.9	32.2									
			LEAN CLAY (CL), gr. & br., low pl., mst. to dry w/wd. silty SH	12.5						5
				5.5						15
867.6	34.5			% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g				35
867.1	35.0	CL-ML	SILTY CLAY (CL-ML), gr., low pl., dry w/wd. silty SH							50
		SH	SHALE: Gray, silty, soft to mod. hard, laminated, slightly effervescent starting at 860.6 and continues to 852.0. Near vertical fracture from 865.5 to 863.6. Vertical fracture 859.8 to 859.5. 20° Fracture at 857.8. 45° Fracture at 856.3.	REC 86% RQD 0% L 0.5	1					
				REC 100% RQD 46%	2					
				L 0.0	3					
	44									

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.09	Hole No. C-04-6
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
852.0	50.1	SH		REC 100%	3	
				RQD 38% L 0.0	4	
847.4	54.7	LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded, fossiliferous.	REC 100% RQD 82% L 0.0	5	
843.5	58.6	SH	SHALE: Dark gray, mod. hard, calcareous in upper 0.6', fossiliferous, laminated. 45° Fracture at 846.9.	REC 100% RQD 86% L 0.0	6, 7	
	68	SS	SANDSTONE: Gray, hard, very fine grained, shaley, thick bedded. Light gray, med. grained and crossbedded from 836.4 to 835.3. 30° Fracture at 829.5. 50° Fracture from 821.2 to 820.8.	REC 100% RQD 98% L 0.0	8	
				REC 100% RQD 96%	9, 10	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.09	Hole No. C-04-6
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L 0.0	10	
				REC 100% RQD 98%	11	
		SS		L 0.0	12	
				REC 100% RQD 94%	13	
823.5	78.6			L 0.0		
		SLS	SILTSTONE: Gray, mod. hard, shaley, laminated.	REC 100% RQD 90%	14	
818.1	84.0			L 0.0		
		SS	SANDSTONE: Light gray, hard, med. grained, crossbedded in thick beds, micaceous, occassional silty-shale laminations and wavy stringers. Shaley, dark gray zone from 807.3 to 806.8 and 806.4 to 805.6. Coal laminations from 797.8 to 797.4. Zone with numerous fractures from 808.4 to 806.7.	REC 100% RQD 88%	15	
				L 0.0	16	
	92			REC 100% RQD 78%	17	

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PROJECT Dover Dam | HOLE NO. C-04-6

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 902.09	Hole No. C-04-6
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 5 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					17	
				L 0.0		
				REC 100%	18	
				RQD 50%		
		SS			19	
				L 0.0		
				REC 100%		
				RQD 84%	20	
				L 0.0		
				REC 100%	21	
				RQD 75%		
796.4	105.7			L 0.0		
			BOTTOM OF HOLE @ 796.4			
	116					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam

HOLE NO. C-04-6

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326657.03 E 2302051.77	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-7	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 12; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 21
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 872.4
	16. DATE HOLE: STARTED 5/19/04; COMPLETED 5/21/04
	17. ELEVATION TOP OF HOLE 886.95 Feet
7. THICKNESS OF OVERBURDEN 28.1 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
8. DEPTH DRILLED INTO ROCK 68.1 Feet	19. NAME OF INSPECTOR STEWART
9. TOTAL DEPTH OF HOLE 96.2 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
		GP	POORLY GRADED GRAVEL WITH SAND (GP), dk. gr., mst., subang. to ang. gravel, c. to f. sand w/LS frags.	6.5						3 3 5
			lt. br., subang. gravel w/SS frags. @ El. 885.4-El.883.9	8.8						10 5 23
883.7	3.3		gr., dry, ang. gravel w/wd. LS @ El. 883.9-El. 883.6	0.9						50/.3

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
880.4	6.6					

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	MC	LL	PL	% +4	% SAND	% -200	BLOWS
879.5	7.5	NS	NO SAMPLE							AUGER
876.5	10.5	GP	POORLY GRADED GRAVEL WITH SAND (GP), gr. br., wet, subang. to ang. gravel w/SS & LS frags.	10.9						6 6 4 5 9 6
873.5	13.5		POORLY GRADED GRAVEL (GP), gr. br., wet, subang. to ang. gravel w/SS frags.	8.9						54 60 51 45 56 51
870.5	16.5	GC	CLAYEY GRAVEL (GC), gr. br., m. pl., wet, subang. to rou. gravel w/ SS frags. & alluvium	26.9			∇ 5/21/04			57 67 21 1 20 1
867.5	19.5	SW	WELL GRADED SAND WITH GRAVEL (SW), wet, subang. to ang. gravel, c. to f. sand w/ SS frags., alluvium and sewer odor	17.9						1 1 1 1 1 WH
867.0	20.0	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), br., low pl., wet, subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	14.0			29	50	21	WH

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PROJECT Dover Dam

HOLE NO. C-04-7

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 886.95 | Hole No. C-04-7

PROJECT: Dover Dam | INSTALLATION: HUNTINGTON DISTRICT | SHEET 2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
864.5	22.5	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), br., low pl., wet, subang. to rou. gravel, c. to f. sand w/SS frags. and alluvium	14.0			29	50	21	WH, 23, 10, 15, 10
863.0	24.0	GP	POORLY GRADED GRAVEL (GP), br., wet, ang. to rou. gravel w/SS frags. and alluvium	8.0						2, 9, 8
		CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. pl., ve. mst. to mst., subang. to rou. gravel, f. sand w/tr. wood frags.	23.1	41	23				3, 6, 7
860.0	27.0		CLAYEY GRAVEL WITH SAND (GC), gr. br., m. pl., mst., ang. to rou. gravel, c. to f. sand w/SS and flint frags, and alluvium	14.3						4, 8, 7
859.2	27.8	GC								12, 46
858.9	28.1	GP	POORLY GRADED GRAVEL WITH SAND (GP), gr. br., mst., subang. to ang. gravel, c. to f. sand w/ calcareous or concrete							50/.1

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		CON	CONCRETE: Drilled without sampling.	REC 100% RQD L 0.0	2	
				REC 100% RQD L 0.0	3	
848.6	38.4			REC 100%	4	
		LS	LIMESTONE: Dark gray, hard to very hard, fossiliferous.	RQD 100% L 0.0	5	
843.2	43.8 44			REC 100% RQD 46%	6	
		SH				

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-7

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.95	Hole No. C-04-7

PROJECT	INSTALLATION	SHEET 3 OF 5 SHEETS
Dover Dam	HUNTINGTON DISTRICT	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE: Dark gray, carbonaceous, mod. hard. Fossiliferous from 843.2 to 842.9. Silty from 843.2 to 842.1.	L 0.0	6	
				REC 100%	7	
839.5	47.5			RQD 39%		
838.8	48.2	C	COAL: Black. Boney coal from 839.5 to 839.0. Vitreous from 839.0 to 838.2. Vertical fracture from 839.5 to 839.0.			
		SS	SANDSTONE: Gray, mod. hard, fine grained laminated and shaley with shale stringers and occassional interbeds. Silty from 817.7 to 817.2. Wavy laminations from 815.8 to 815.6.	L 0.0	8	
				REC 100%	9	
				RQD 100%		
				L 0.0		
				REC 100%	10	
				RQD 100%	11	
				L 0.0		
				REC 100%	12	
				RQD 100%		
				L 0.0		
	68			REC 100%	13	

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MAY 04

PROJECT Dover Dam | HOLE NO. C-04-7

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.95	Hole No. C-04-7
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS		RQD 92%	13	
815.6	71.4			L 0.0	14	
		SLS	SILTSTONE: Gray, mod. hard, laminated, shaley, effervescent. Vertical fracture from 813.3 to 813.0.	REC 100%		
				RQD 76%	15	
				L 0.0		
809.1	77.9			REC 100%	16	
		SS	SANDSTONE: Light gray, hard, crossbedded, med. to coarse grained, micaceous. Several very thin lenses of dark gray, very soft clay from 807.9 to 807.8. Vertical surface crack from 804.0 to 803.8, Coal stringers from 798.5 to 798.2. Coal laminations averaging 0.01' thick from 792.6 to 791.5. Vertical fracture from 791.9 to 791.5.	RQD 90%		
				L 0.0		
				REC 100%	17	
				RQD 90%	18	
				L 0.0		
				REC 100%	19	
				RQD 84%		
				L 0.0	20	
	92			REC 100%		

LRH FORM 1836-A MAY 04

PROJECT Dover Dam | HOLE NO. C-04-7

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.95		Hole No. C-04-7			
PROJECT Dover Dam		INSTALLATION HUNTINGTON DISTRICT		SHEET 5 OF 5 SHEETS		
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS		RQD 78%	20	
					21	
790.8	96.2			L 0.0		
			BOTTOM OF HOLE @ 790.8			
	116					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam

HOLE NO. C-04-7

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326222.98 E 2302153.36	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 18 : UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 17
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 869.3
	16. DATE HOLE: STARTED 6/4/04 : COMPLETED 6/5/04
7. THICKNESS OF OVERBURDEN 27.3 Feet	17. ELEVATION TOP OF HOLE 885.38 Feet
8. DEPTH DRILLED INTO ROCK 56.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 99.3%
9. TOTAL DEPTH OF HOLE 83.3 Feet	19. NAME OF INSPECTOR KISER

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
885.1	0.3	NS	NO SAMPLE - TOPSOIL							
882.4	3.0	CL	SANDY LEAN CLAY (CL), br. gr., low pl., mst., f. sand w/tr. org. and SH frags.	13.5						3, 4, 4, 3, 4, 4
		GC	CLAYEY GRAVEL WITH SAND (GC), br. gr., low pl., mst., subang. gravel, f. sand w/SH and SS frags.	11.1			30	21	49	3, 4, 5
879.4	6.0	GC	br. and gr. w/SLS frags. @ El. 880.8-El. 879.3	10.6	28	19	30	29	41	3, 3, 4
877.9	7.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), br. gr., low pl., mst., subang. to rou. gravel, f. sand w/ SS frags. and alluvium	14.8			25	24	51	3, 3, 4
876.4	9.0	CL	SANDY LEAN CLAY WITH GRAVEL (CL), br. gr., low pl., mst., subang. to rou. gravel, f. sand w/tr. SH frags., flint, and alluvium	14.3	30	20	20	29	51	4, 6, 9
874.9	10.5	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), br. gr., low pl., mst., ang. to rou. gravel, f. sand w/tr. org., SS frags., and alluvium	11.6			23.4	14.6	35	4, 6, 9
		GM	SILTY GRAVEL WITH SAND (GM), br. & gr., low to non pl., mst., ang. to rou. gravel, c. to f. sand w/flint and SS frags.	7.2						18, 32, 18
871.8	13.5	GM	br. gr., low pl. w/alluvium @ El. 873.3-El. 871.8	12.1	29	23				7, 7, 7
		SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), br. gr., low pl., mst., ang. to rou. gravel, c. to f. sand w/flint, alluvium, and SS frags.	9.0			35	37	28	4, 11, 9
868.9	16.5	SC-SM	br. and gr., subang. to rou. gravel @ El. 870.3-El. 868.8	9.0			▽ 6/4/04			7, 9, 12
867.3	18.0	GC	CLAYEY GRAVEL WITH SAND (GC), gr., low pl., wet to ve. mst., subang. gravel, c. to f. sand w/SS and SLS frags.	13.8			36	35	29	4, 4, 8
865.9	19.5	GW-GC	WELL GRADED GRAVEL WITH SAND AND SILTY CLAY (GW-GC), br., low pl., wet, subang. to ang. gravel, c. to f. sand w/SS and SLS frags.	12.7						7, 11, 10
865.4	20.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), dk. gr., m. to low pl., ve. mst. to mst., subang. gravel, f. sand w/SS and SH frags.	13.9						2

LRH FORM 1836 MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-8

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 885.38	Hole No. C-04-8
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
862.9	22.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), dk. gr., m. to low pl., ve. mst. to mst., subang. gravel, f. sand w/SS and SH frags. gr. br., low pl., ve. mst. @ El. 864.3-El. 862.8	13.9 16.4	27	18				11, 6, 3, 5, 6
861.4	24.0	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr., m. pl., ve. mst., f. sand	17.9						2, 2, 3
859.9	25.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. pl., ve. mst. to mst., subang. gravel, f. sand w/ SS and SH frags. and alluvium	11.4			34	15	51	5, 5, 32
858.2	27.3	GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), gr. & br., low pl., mst. to dry, subang. to ang. gravel, c. to f. sand w/wd. sandy SH frags.	9.6 8.6						26, 9, 9, 50/.3

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
854.2	31.2	SLS	Siltstone boulders and cobbles overlying about 0.8' of sandy lean clay with gravel.	REC 95% RQD N/A L 0.2	1	
849.4	36.0	LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded grading into underlying shale at 849.4, fossiliferous.	REC 96% RQD 96% L 0.2	2	
844.5	40.9	SH	SHALE: Dark gray to black, mod. hard, laminated, carbonaceous, fossiliferous in upper portion. 30° Fracture at 848.8.	REC 100% RQD 34% L 0.0	3	
				REC 100%	4	
844.3	41.1	C	COAL: Black, vitreous.			
841.9	43.5	SH	SHALE: Gray, mod. hard, silty, laminated, gradational into underlying sandstone at 842.8.	RQD 44% L 0.0	5	
	44	SS				

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-8

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 885.38	Hole No. C-04-8

PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS	SANDSTONE: Light gray to gray, mod. hard, very fine grained, very silty, thin to thick bedded.	REC 100% RQD 96% L 0.0	6	
				REC 100% RQD 90% L 0.0	7	
833.0	52.2				8	
		SS	SANDSTONE: Light gray to gray, mod. hard to hard, fine to medium grained, zones silty, thin to thick bedded, occassional shale stringers and laminations throughout, cross-bedded zones below 825.6, micaceous. Sholey from 830.4 to 829.2. Shale layer, dark gray from 820.4 to 820.2.	REC 100% RQD 94% L 0.0	9	
				REC 100% RQD 88% L 0.0	10	
					11	
820.2	65.2			REC 100%	12	
	68	SS	SANDSTONE: Light gray to gray, mod. hard to hard, medium to coarse grained, thin to thick bedded, occassional shale stringers and laminations and zones throughout, zones cross-bedded, micaceous.	RQD 96% L 0.0	13	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 885.38	Hole No. C-04-8
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 4 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
		SS	Sandstone continued: Occassional coal stringers and laminations from 812.8 to 803.6, especialy at 804.9.	REC 100% RQD 87% L 0.0	14	
				REC 100% RQD 86% L 0.0	15 16	
				REC 100% RQD 65%	17	
802.1	83.3			L 0.0		
	92		BOTTOM OF HOLE @ 802.1			

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-8

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326266.66 E 2302196.73	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-9	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 16; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 16
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 870.0
	16. DATE HOLE: STARTED 6/3/04; COMPLETED 6/4/04
7. THICKNESS OF OVERBURDEN 30.1 Feet	17. ELEVATION TOP OF HOLE 884.82 Feet
8. DEPTH DRILLED INTO ROCK 52.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 82.1 Feet	19. NAME OF INSPECTOR KISER

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
883.3	1.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), br., low pl., mst., subang. gravel, f. sand w/SH frags.	14.9						3, 3, 3
881.8	3.0	CL	SANDY LEAN CLAY (CL), br., m. pl., mst., f. sand w/tr. SH frags.	16.3	33	21				2, 3, 3
880.3	4.5	GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), br., low pl., mst., subang. gravel, f. sand	10.1						4, 6, 7
		SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr., low pl., mst., subang. to rou. gravel, f. sand	13.8			16	44	40	4, 4, 6
877.3	7.5			15.0						2, 4, 10
875.8	9.0	GM	SILTY GRAVEL WITH SAND (GM), dk. gr., low to non pl., mst., subang. to ang. gravel, f. sand w/ SLS frags.	11.3						20, 17, 5
874.3	10.5	CL-ML	GRAVELLY SILTY CLAY WITH SAND (CL-ML), gr. br., low pl., mst., subang. gravel, f. sand w/ tr. SH frags.	14.2			25	24	51	2, 1, 1
872.8	12.0	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr. br., low pl., mst., subang. gravel, f. sand w/ SS frags.	11.4			35	41	24	2, 5, 3
		GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), gr. br., low pl., ve. mst., subang. to rou. gravel, f. sand w/SS frags. and alluvium	15.5						2, 4, 8
868.3	16.5		wet @ El. 871.3-El. 868.3	15.5			▽ 6/3/04 40	39	21	2, 4, 4, 6, 3, 1
865.3	19.5	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr. br., low pl., wet, ang. gravel, c. to f. sand w/SS frags. and alluvium	16.1			39	41	20	2, 1, 2, 0, 0, 1
864.8	20.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), m. pl., wet to ve. mst., subang. to rou. gravel, c. to f. sand	20.5			29	20	51	0

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-9

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 884.82 | Hole No. C-04-9

PROJECT Dover Dam | INSTALLATION HUNTINGTON DISTRICT | SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
862.3	22.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), m. pl., wet to ve. mst., subang. to rou. gravel, c. to f. sand	20.5			29	20	51	0 1 0 1 1
		GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., low pl., wet, subang. gravel, f. sand w/SH and SS frags.	22.7	32	22	31	20	49	WH WH WH 0 0 1
			m. pl. @ El. 859.3-El. 854.8	23.4	36	22	31	20	49	0 1 2
				25.4			31	20	49	0 0 1
854.8	30.0		gr., subang. to ang. gravel w/SS and flint frags. @ El. 856.3-El. 854.8	21.3						1 2 3 50/.1
854.7	30.1	NS	NO RECOVERY							

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
850.3	34.5	LS	LIMESTONE: Gray, hard, fine to med. crystaline grained, medium to thick bedded, grades into underlying shale at 850.3, fossiliferous. Near vertical fracture from 854.7 to 854.0. Weathered bedding plane at 850.3.	REC 100% RQD 68% L 0.0 REC 100% RQD 86%	1	
845.9	38.9	SH	SHALE: Dark gray to black, mod. hard, laminated, carbonaceous, fossiliferous in upper part. Near vertical fracture from 846.2 to 845.7.	L 0.0 REC 100% RQD 49%	2 3	
845.7	39.1	C	COAL: Black, vitreous			
843.8	41.0	SH	SHALE: Gray, mod. hard, laminated, silty to sandy, grades into very fine grained sandstone below 843.8.	L 0.0 REC 100%		
	44	SS	SANDSTONE: Gray, mod. hard, very fine grained, silty, thin to thick bedded, grades to siltstone below 836.9.	RQD 92% L 0.0	4	

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-9

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 884.82	Hole No. C-04-9
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
		SS		REC 100%	5	
				RQD 98%	6	
836.9	47.9					
		SLS	SILTSTONE: Gray, mod. hard, shaley, sandy, laminated to thin bedded.	L 0.0		
				REC 100%		
834.2	50.6					
		SS	SANDSTONE: Gray, mod. hard to hard, fine to medium grained, cross-bedded, micaeous, scattered shaley stringers and laminations. Sitly to shaley from 831.3 to 830.7 and from 829.0 to 828.6. Shaley from 828.2 to 828.1, 826.9 to 826.8, and from 822.7 to 822.6.	RQD 100%	7	
				L 0.0		
				REC 100%	8	
				RQD 80%		
				L 0.0	9	
				REC 100%		
				RQD 98%	10	
820.7	64.1			L 0.0		
		SS	SANDSTONE: Light gray to gray, mod. hard to hard, medium to coarse grained, zones cross-bedded, medium to thick bedded, occassional shale stringers and laminations throughout, micaceous. Shaley from 818.5 to 818.3. Shale layer at 20° angle from 812.8 to 812.0.	REC 100%	11	
				RQD 94%		
	68		(continued on following page)	L 0.0		

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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 884.82 | Hole No. C-04-9

PROJECT Dover Dam | INSTALLATION HUNTINGTON DISTRICT | SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SS	SANDSTONE: Continued from previous page 20° Fracture at 812.4. 20° Fracture along coal lamination at 804.7. Several coaly laminations from about 804.7 to 802.7.	REC 100% RQD 86% L 0.0	12 13	
				REC 100% RQD 86% L 0.0	14	
				REC 100% RQD 87% L 0.0	15 16	
	92		BOTTOM OF HOLE @ 802.7			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-9

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 4 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326328.49 E 2302312.07	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-10	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 20; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 16
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 863.1
	16. DATE HOLE: STARTED 6/7/04; COMPLETED 6/8/04
7. THICKNESS OF OVERBURDEN 29.7 Feet	17. ELEVATION TOP OF HOLE 886.15 FEET
8. DEPTH DRILLED INTO ROCK 52.3 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 82.0 Feet	19. NAME OF INSPECTOR KISER

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
885.9	0.3	NS	NO SAMPLE-TOPSOIL							
884.7	1.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand	16.4						1, 2, 4
883.2	3.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/SH and SS frags.	14.3						3, 4, 5
		GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., m. pl., mst., subang. to rou. gravel, c. to f. sand w/ alluvium	13.1						2, 3, 7
880.2	6.0	GC	gr., low pl. w/SS frags. @ El. 881.6-El. 880.1	12.9	27	19				4, 4, 4
879.0	7.2	GP-GM	POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM), gr., non pl., mst., subang. to ang. gravel, c. to f. sand w/wd. SS	6.2			61	28	11	26, 40, 50/.2
878.7	7.5	NS	NO SAMPLE							AUGER
877.2	9.0	GM	SILTY GRAVEL WITH SAND (GM), gr., non pl., dry, subang. to ang. gravel, c. to f. sand w/SS and SLS frags	8.3						7, 7, 12
875.7	10.5	GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., low pl., mst., subang. to ang. gravel, f. sand	11.7	29	19				4, 5, 4
874.2	12.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/SS frags.	17.4						2, 3, 3
872.7	13.5	GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., low pl., mst., subang. to ang. gravel, c. to f. sand w/SS frags. and alluvium	17.0			30	21	49	3, 16, 9
871.2	15.0	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr. & br., low pl., mst., subang. to rou. gravel, f. sand	13.2						1, 5, 5
869.7	16.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), lt. br., m. to low pl., mst., subang. gravel, f. sand w/SS frags.	15.7						3, 3, 6
868.2	18.0	CL	LEAN CLAY WITH SAND (CL), m. pl., mst., f. sand	17.5	37	22				3, 4, 6
866.7	19.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/SH frags.	16.2						4, 5, 8
866.2	20.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. to low pl., mst., subang. gravel w/wd. sandy SH and SH frags.	15.7						4

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-10

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.15	Hole No. C-04-10
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
865.2	21.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. to low pl., mst., subang. gravel w/wd. sandy SH frags.	15.7						4 7
863.7	22.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/SH frags.	16.4	35	21				3 5 6
862.2	24.0	GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., m. to low pl., mst., subang. gravel, c. to f. sand w/ SS frags.	14.0			▽ 6/7/04			3 5 6
860.7	25.5	GP-GM	POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM), gr. br., non pl., wet to ve. mst., subang. gravel, c. to f. sand w/ SS frags.	12.4						6 11 24
859.2	27.0	SM	SILTY SAND WITH GRAVEL (SM), gr. br., non pl., wet, subang. gravel, c. to f. sand w/SS frags.	15.2			25	54	21	6 10 6
857.7	28.5	CL	LEAN CLAY WITH SAND (CL), gr., low pl., mst., f. sand w/wd. SH frags.	12.6						5 9 18
856.5	29.7	CL-ML	SILTY CLAY (CL-ML), gr., low pl., mst. w/wd. silty SH	11.5						19 39 50/.2

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	REC / RQD	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
851.9	34.3	LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thin to thick bedded, grades into underlying shale at 851.8, fossiliferous. Vertical fracture from 856.4 to 855.6.	REC 100% RQD 49% L 0.0 REC 100% RQD 82%	1	
848.0	38.2	SH	SHALE: Dark gray to black, mod. hard, laminated, carbonaceous, fossiliferous in upper part.	L 0.0 REC 100%	2 3	
847.9	38.3	C	COAL: Black, low quality (sholey)	RQD 67%		
845.2	41.0	SH	SHALE: Gray to dark gray, soft to mod. hard, laminated, silty.	L 0.0	4	
	44	SLS	SILTSTONE: Gray, mod. hard, silty to sandy, zones very sandy, thin to thick bedded. Sandy zone from 842.1 to 840.0.	REC 100% RQD 98% L 0.0	5	

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam

HOLE NO. C-04-10

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.15	Hole No. C-04-10
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SLS			5	
				REC 100%	6	
838.0	48.2					
		SS	SANDSTONE WITH INTERBEDDED SHALE: Sandstone is gray, mod. hard to hard, fine to medium grained, thin to thick bedded, micaeous, occasional shale stringers. Shale is gray, mod. hard, silty to sandy, laminated, thin bedded. Siltstone zone from 835.1 to 834.1.	RQD 100% L 0.0	7	
				REC 100% RQD 90% L 0.0	8	
				REC 100% RQD 76%	9	
827.4	58.8					
		SS	SANDSTONE: Gray, hard, fine to medium grained, thin to thick bedded, micaeous, shaley zones. Shaley zone from 821.0 to 820.8 and from 817.9 to 817.5.	L 0.0	10	
				REC 100% RQD 93% L 0.0	11	
	68			REC 100%	12	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 886.15	Hole No. C-04-10
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
817.6	68.6	SS				
		SS	SANDSTONE: Light gray to gray, hard, medium to coarse grained, thin to thick bedded, micaeous, cross-bedded in zones with occasional carbonaceous and coal stringers and laminations. Clayey lamination (about one-sixteenth inch thick) at 812.9. Cooly and shaley zone from 806.8 to 806.4. Shaley zone from 805.8 to 805.7. Zone of numerous coal stringers from 804.6 to 804.1.	RQD 78% L 0.0 REC 100% RQD 84% L 0.0 REC 100% RQD 86% L 0.0 REC 100% RQD 60% L 0.0	13 14 15 16	
804.2	82.0					
			BOTTOM OF HOLE @ 804.2			
	92					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-10

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 2 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION *(Coordinates or Station)* N 326188.34 E 2302264.46	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. *(As shown on drawing title and file number)* C-04-11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED 12 : UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 3
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 888.4
	16. DATE HOLE : STARTED 6/6/04 : COMPLETED 6/6/04
7. THICKNESS OF OVERBURDEN 19.0 Feet	17. ELEVATION TOP OF HOLE 901.80 FEET
8. DEPTH DRILLED INTO ROCK 10.3 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 29.3 Feet	19. NAME OF INSPECTOR KISER

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
901.4	0.4	NS	NO SAMPLE-TOPSOIL							1
900.3	1.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), br., low pl., mst. to dry, subang. gravel, f. sand	12.6						4, 4
898.8	3.0	CL	SANDY LEAN CLAY (CL), br., m. pl., mst., f. sand	15.6						4, 4, 6
897.3	4.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/tr. wood frags.	15.7			19	21	60	4, 6, 6
895.8	6.0	GC	CLAYEY GRAVEL WITH SAND (GC), br., m. pl., mst., subang. to rou. gravel, c. to f. sand	14.3	32	20				3, 3, 5
894.3	7.5	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. to low pl., mst., subang. gravel, f. sand w/ SH frags.,	16.4			25	24	51	3, 3, 3
892.8	9.0	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. to low pl., mst., subang. to rou. gravel, f. sand	17.9						3, 3, 4
891.3	10.5	CL	SANDY LEAN CLAY (CL), gr., m. pl., mst., f. sand	19.7			11	36	53	3, 3, 3
889.8	12.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/SS and SH frags.	13.7	30	21				2, 5, 5
888.3	13.5	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand	14.5				▽ 6/6/04		3, 3, 5
886.8	15.0	SC	CLAYEY SAND WITH GRAVEL (SC), gr. br., m. pl., mst., subang. gravel, f. sand	9.8	29	18				2, 3, 3
885.3	16.5	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), low pl., mst., subang. gravel, c. to f. sand w/ SS frags.	12.4			40	40	20	3, 3, 3
882.9	18.9	GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), low pl., mst., subang. gravel, c. to f. sand w/ SS and SLS frags.	11.0						3, 15, 3, 3, 50/.4
882.8	19.0	NS	NO RECOVERY							50/.1

				% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, fossiliferous.			

LRH FORM 1836 MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-11

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 901.80	Hole No. C-04-11
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
881.3	20.5	LS	60° Fracture from 882.8 to 882.3.	REC 100%	1	
880.6	21.2	C	COAL: Black, vitreous, shaley zone from 881.0 to 880.8	RQD 22%		
877.1	24.7	SH	SHALE: Gray, soft to mod. hard, silty to clayey, laminated, grades into silty to sandy shale below 877.1. Vertical fracture from 876.8 to 876.3.	L 0.0 REC 100% RQD 0%	2	
872.5	29.3	SH	SHALE: Gray, mod. hard, silty to sandy, zones very sandy, occasional siderite nodules below 874.8. Near vertical fracture from 875.2 to 874.8. Iron stained zone from 874.8 to 873.3. Weathered and water stained near vertical fracture from 874.6 to 873.3. Vertical fracture from 873.2 to 872.9.	L 0.0 REC 100% RQD 19% L 0.0	3	
	44		BOTTOM OF HOLE @ 872.5			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-11

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 2 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION *(Coordinates or Station)* N 326271.34 E 2302355.30	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. *(As shown on drawing title and file number)* C-04-12	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED 11 : UNDISTURBED 0
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES 3
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 877.2
	16. DATE HOLE : STARTED 6/14/04 : COMPLETED 6/14/04
7. THICKNESS OF OVERBURDEN 23.7 Feet	17. ELEVATION TOP OF HOLE 901.71 FEET
8. DEPTH DRILLED INTO ROCK 10.6 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 34.3 Feet	19. NAME OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
901.1	0.6	CL-ML	GRAVELLY SILTY CLAY WITH SAND (CL-ML), gr. br., low pl., ve. mst., subang. to rou. gravel, f. sand w/tr. rts., SH frags. and org. odor				30	19	51	2
898.7	3.0	CL-ML	SANDY SILTY CLAY WITH GRAVEL (CL-ML), gr. br., low pl., mst., subang. gravel, f. sand	14.5						4, 4, 11, 7, 5
895.7	6.0	CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand w/chemical odor	15.3	33	21				3, 3, 8, 2, 3, 56
892.7	9.0	GC-GM	SILTY CLAYEY GRAVEL WITH SAND (GC-GM), low pl., mst., subang. to ang. gravel, f. sand w/SLS frags.	10.7						73, 8, 57, 7, 6, 3
		CL	SANDY LEAN CLAY WITH GRAVEL (CL), gr. br., m. pl., mst., subang. gravel, f. sand	15.8			20	29	51	2, 3, 3, 2, 2, 2
886.7	15.0	CL	low pl. @ El. 889.7-El. 886.7	16.9	30	21	20	29	51	2, 2, 3, 7, 3, 4
884.2	17.5	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr. br., low pl., mst., subang. to rou. gravel, c. to f. sand w/SS frags.	12.9			29	39	32	3, 5, 5, 4, 3
882.2	19.5	CH	FAT CLAY (CH), dk. gr., hi. pl., mst. w/SH frags.	23.4	51	27				3, 2, 9, 4
881.7	20.0	CH	FAT CLAY (CH), dk. gr., hi. pl., ve. mst.	31.1						2

LRH FORM 1836
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-12

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 901.71	Hole No. C-04-12
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
881.5	20.2	CH	FAT CLAY (CH), dk. gr., hi. pl., ve. mst.	31.1						4
		CL-ML	SILTY CLAY (CL-ML), lt. gr., low pl., mst. to dry w/wd. silty SH	9.5						10, 9, 29, 25
				9.6						18, 40, 50/.2
878.0	23.7									

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
		SH	SHALE: Gray, soft to mod. hard, silty to shaley, brown ironed staining along beddingt planes, weathered at top. Near vertical fracture from 871.4 to 870.9. Highly fractured and iron stained zone from 870.9 to 870.0. Silty from 870.0 to 867.5. 30° Fracture at 868.0.	REC 100% RQD 0% L 0.0	1	▽ 6/14/04
				REC 100% RQD 0% L 0.0	2	
870.9	30.8					
		SH	SHALE: Gray, mod. hard, silty to sandy.	REC 100% RQD 27% L 0.0	3	
867.4	34.3					
			BOTTOM OF HOLE @ 867.4			
	44					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-12

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION (Coordinates or Station) N 326143.71 E 2302370.21	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. (As shown on drawing title and file number) C-04-13	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 7; UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 24
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 920.4
	16. DATE HOLE: STARTED 5/25/04; COMPLETED 6/2/04
7. THICKNESS OF OVERBURDEN 16.9 Feet	17. ELEVATION TOP OF HOLE 934.03 Feet
8. DEPTH DRILLED INTO ROCK 82.0 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
9. TOTAL DEPTH OF HOLE 98.9 Feet	19. NAME OF INSPECTOR STEWART

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
931.0	3.0	SC	CLAYEY SAND WITH GRAVEL (SC), gr., m. pl., mst., subang. gravel, c. to f. sand w/wood frags.	33.5	39	28				3, 3, 5 / 3, 4, 7
928.0	6.0	SC-SM	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), gr. br., low pl., mst., subang. to rou. gravel, c. to f. sand	9.5			35	39	26	4, 7, 8 / 6, 6, 5
920.0	14.0	CL-ML	GRAVELLY SILTY CLAY WITH SAND (CL-ML), gr. br., low pl., mst., subang. gravel, f. sand w/tr. wood frags.	12.9						4, 7, 8 / 2, 3, 4
			no wood frags. @ El. 925.0-El. 920.0	17.3	35	22				2, 2, 2 / 1, 2, 3
			ve. mst. @ El. 922.0-El. 920.0	20.8			∇ 6/1/04			1, 2, 3
917.1	16.9		GRAVELLY SILTY CLAY (CL-ML), gr., low pl., dry, ang. gravel w/wd. silty SH	4.6						4, 17, 25 / 18, 50, 27
				4.2						50/.4

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
916.4	17.6	SH	SHALE: Dark gray to black, soft to mod. hard, silty, laminated.			
916.1	17.9	C	BONE COAL: Black			
		SS	SANDSTONE: Gray, hard, med. to coarse grained, micaceous, cross-bedded in thin to thick beds. Iron stained zone from 902.3 to 900.9.	REC 100% RQD 99% L 0.0 REC 100%	1	

LRH FORM 1836 MAY 04

PROJECT Dover Dam | HOLE NO. C-04-13

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 934.03	Hole No. C-04-13

PROJECT	INSTALLATION	SHEET
Dover Dam	HUNTINGTON DISTRICT	2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			SANDSTONE continued: Vertical fracture from 892.0 to 890.7. Iron stained zone from 893.0 to 889.7. Vertical fracture from 890.5 to 889.7.	RQD 92% L 0.0	2	
				REC 100% RQD 93%	3	
				L 0.0	4	
		SS		REC 100% RQD 100% L 0.0	5	
				REC 100% RQD 100% L 0.0	6	
				REC 100%	7	
	44			RQD 62% L 0.0	8	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 934.03	Hole No. C-04-13
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
889.7	44.3	SS		REC 100%		
		SH	SHALE: Dark gray, mod. hard, laminated, scattered siderite nodules.	RQD 52%	9	
885.0	49.0			L 0.0		
		LS	LIMESTONE: Gray, hard, fine to medium crystalline grained, fossiliferous, thin bedded.	REC 100%	10	
883.0	51.0					
882.2	51.8	C	COAL: Black, vitreous, interbedded with very few shale laminations. Healed vertical fracture from 883.9 to 883.0	RQD 78%		
880.8	53.2	SS	SANDSTONE: Light gray, mod. hard to hard, very fine grained, fossiliferous, silty. Black in color from 882.2 to 884.2. 30° Fracture at 880.6.	L 0.0	11	
879.4	54.6	SH	SHALE: Gray, mod. hard, silty, thin to thick bedded, occasional carbonaceous shale stringers. 30° Fracture at 878.2.	REC 100%		
876.1	57.9	SH/SS	INTERBEDDED SANDSTONE AND SHALE: Light gray (SS), dark gray (SH), mod. hard to hard.	RQD 100%	12	
		SH	SHALE: Dark gray, mod. hard	L 0.0		
				REC 100%	13	
				RQD 100%		
				L 0.0	14	
				REC 100%		
				RQD 100%	15	
	68					

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam | HOLE NO. C-04-13

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 904.03		Hole No. C-04-13
PROJECT Dover Dam		INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L 0.0		
				REC 100%		
				RQD 100%	16	
		SH		L 0.0	17	
				REC 100%		
				RQD 100%	18	
855.0	79.0			L 0.0		
		LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded grading into underlying shale at 849.5, fossiliferous.	REC 100%	19	
				RQD 90%		
				L 0.0		
849.5	84.5			REC 100%	20	
		SH	SHALE: Dark gray to black, mod. hard, silty, laminated, carbonaceous, fossiliferous in upper part.	RQD 96%		
					21	
				L 0.0		
844.7	89.3					
844.4	89.6	C	COAL: Black, vitreous.	REC 100%		
		SH	SHALE: Gray, mod. hard, silty, thin to thick bedded.		22	
	92			RQD 80%		

LRH FORM 1836-A MAY 04 | PROJECT Dover Dam | HOLE NO. C-04-13

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 934.03	Hole No. C-04-13

PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 5 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
839.5	94.5	SH		L 0.0 REC 100%	23	
835.1	98.9	SS	SANDSTONE: Gray, mod. hard to hard, very fine grained, micaceous, shaley.	RQD 100% L 0.0	24	
	116		BOTTOM OF HOLE @ 835.1			

LRH FORM 1836-A
MAY 04

PROJECT Dover Dam	HOLE NO. C-04-13

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DRILLING LOG	DIVISION Great Lakes and Ohio River	INSTALLATION CELRH-EC-G	SHEET 1 OF 5 SHEETS

1. PROJECT Dover Dam	10. SIZE AND TYPE OF BIT 4" CORE AND 3" HOLLOW
2. LOCATION *(Coordinates or Station)* N 326162.96 E 2302396.76	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NGVD 29
3. DRILLING AGENCY HC NUTTING	12. MANUFACTURER'S DESIGNATION OF DRILL CME 45
4. HOLE NO. *(As shown on drawing title and file number)* C-04-14	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8 : UNDISTURBED 0
5. NAME OF DRILLER BRAGG	14. TOTAL NUMBER CORE BOXES 25
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED 0 DEG. FROM VERT.	15. ELEVATION GROUND WATER 918.1
	16. DATE HOLE: STARTED 5/23/04 : COMPLETED 5/24/04
	17. ELEVATION TOP OF HOLE 933.94 Feet
7. THICKNESS OF OVERBURDEN 18.3 Feet	18. TOTAL CORE RECOVERY FOR BORING 100%
8. DEPTH DRILLED INTO ROCK 82.8 Feet	19. NAME OF INSPECTOR STEWART
9. TOTAL DEPTH OF HOLE 101.1 Feet	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	MC	LL	PL	% +4	% SAND	% -200	BLOWS
930.9	3.0	CL	GRAVELLY LEAN CLAY WITH SAND (CL), gr., m. to low pl., mst., subang. to ang. gravel, c. to f. sand w/flint and coal frags.				30	19	51	2 2 2 3 5 12
927.9	6.0	GC	CLAYEY GRAVEL WITH SAND (GC), gr. br., m. pl., mst., subang. gravel, c. to f. sand	9.3	32	21				5 10 10 4 4 5
924.9	9.0	SC	CLAYEY SAND WITH GRAVEL (SC), gr. and br., m. pl., mst., subang. to rou. gravel, c. to f. sand	17.2			19	33	48	2 4 4 2 3 4
		CL	LEAN CLAY WITH GRAVEL (CL), gr., m. pl., mst., subang. gravel	19.5	35	23				1 3 4 2 2 3
920.9	13.0		SH and SS frags. @ El. 921.9-El. 920.9	15.9						2 2
918.9	15.0		SILTY CLAY (CL-ML), gr., low pl., dry w/wd. silty SH	6.9						18 6 15 16
915.9	18.0	CL-ML	SILTY CLAY WITH GRAVEL (CL-ML), gr., low pl., dry, subang. gravel w/wd. SH	5.1			▽ 5/24/04			19 25 44 15 26 42
915.6	18.3	CL	LEAN CLAY (CL), low pl., mst. to dry w/wd. silty SH	9.6						50/.3

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
915.0	18.9	SH	SHALE: Dark gray to black, soft to mod. hard, silty, laminated.			
914.7	19.2	C	BONE COAL: Black			
		SS	SANDSTONE: (description on following page)	REC 100%	1	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.94	Hole No. C-04-14
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 2 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			SANDSTONE: Ligth gray and gray, hard, med. to coarse grained, micaceous, cross-bedded in thin to thick beds.	RQD 30% L 0.0	1	
			Vertical fracture from 913.9 to 912.9.	REC 100%	2	
			45° Fracture at 912.0.			
			45° Fracture at 910.9.			
			Occasional coal stringers from 909.9 to 907.2.	RQD 85%		
			30° Fracture at 907.1.	L 0.0		
				REC 100%	3	
				RQD 98%	4	
		SS		L 0.0		
				REC 100%	5	
				RQD 100%		
				L 0.0		
				REC 100%	6	
				RQD 100%	7	
				L 0.0		
				REC 100%		
	44			RQD 94%	8	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.94	Hole No. C-04-14
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 3 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
889.7	44.2	SS				
883.2	50.7	SH	SHALE: Dark gray, mod. hard, laminated, silty. 45° Fracture at 889.3. 45° Fracture at 887.0. Slickensided at 885.6. Vertical fracture and siderite from 884.6 to 884.3. Carbonaceous and fossiliferous zone from 884.3 to 883.2.	L 0.0 REC 100% RQD 82%	8 9	
882.1	51.8	LS	LIMESTONE: Gray to dark gray, hard, fine to med. crystalline grained, fossiliferous, thin bedded.	L 0.0 REC 100%	10	
881.1	52.8	C	COAL: Black, vitreous, pyritic.			
879.8	54.1	SS	SANDSTONE: Light gray, mod. hard to hard, very fine grained, silty.	RQD 72%		
877.8	56.1	SH	SHALE: Gray, mod. hard, laminated. 45° Fracture at 879.1.	L 0.0	11	
874.0	59.9	SH/SS	INTERBEDDED SANDSTONE AND SHALE: Light gray (SS), dark gray (SH), mod. hard to hard. 60° Fracture from 859.6 to 859.0.	REC 100% RQD 100%	12	
	68	SH	SHALE: Dark gray, mod. hard. Effervescent from 874.9 to 854.0.	L 0.0 REC 100% RQD 100% L 0.0 REC 100%	13 14 15	

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DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.94	Hole No. C-04-14
PROJECT Dover Dam	INSTALLATION HUNTINGTON DISTRICT	SHEET 4 OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				RQD 100%	15	
				L 0.0 REC 100%	16	
		SH		RQD 88%		
				L 0.0 REC 100%	17	
854.0	79.9			RQD 92%	18	
		LS	LIMESTONE: Gray, hard, fine to med. crystalline grained, thick bedded, fossiliferous.	L 0.0 REC 100%	19	
848.5	85.4			RQD 86%	20	
		SH	SHALE: Dark gray to black, mod. hard, laminated, carbonaceous, fossiliferous in upper part. 35° Fracture with slight slickensides at 848.4. Slickensided at 845.6. 45° Fracture at 845.5.	L 0.0 REC 100%		
844.2	89.7			RQD 68%	21	
843.9	90.0	C	COAL: Black, vitreous.			
	92	SH	SHALE: Gray, mod. hard, silty, laminated. 45° Fracture with slickensides at 843.8. (Continued on following page)	L 0.0 REC 100%	22	

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 933.94	Hole No. C-04-14

PROJECT	INSTALLATION	SHEET 5
Dover Dam	HUNTINGTON DISTRICT	OF 5 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		SH	SHALE continued: 60° Fracture with slickensides from 842.9 to 842.4. 45° Fracture with slight slickensides at 841.9. 45° Fracture at 840.3.	RQD 74%	22	
838.3	95.6			L 0.0	23	
		SS	SANDSTONE: Gray, hard, fine grained, micaceous, shaley. Silty zone from 838.3 to 836.7. Silty zone from 834.0 to 833.0	REC 100% RQD 100%	24	
833.0	100.9			L 0.0	25	
	116		BOTTOM OF HOLE @ 833.0			

LRH FORM 1836-A
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PROJECT	HOLE NO.
Dover Dam	C-04-14

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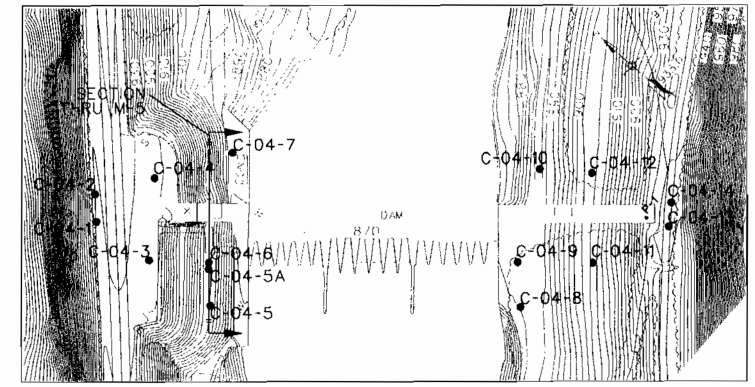
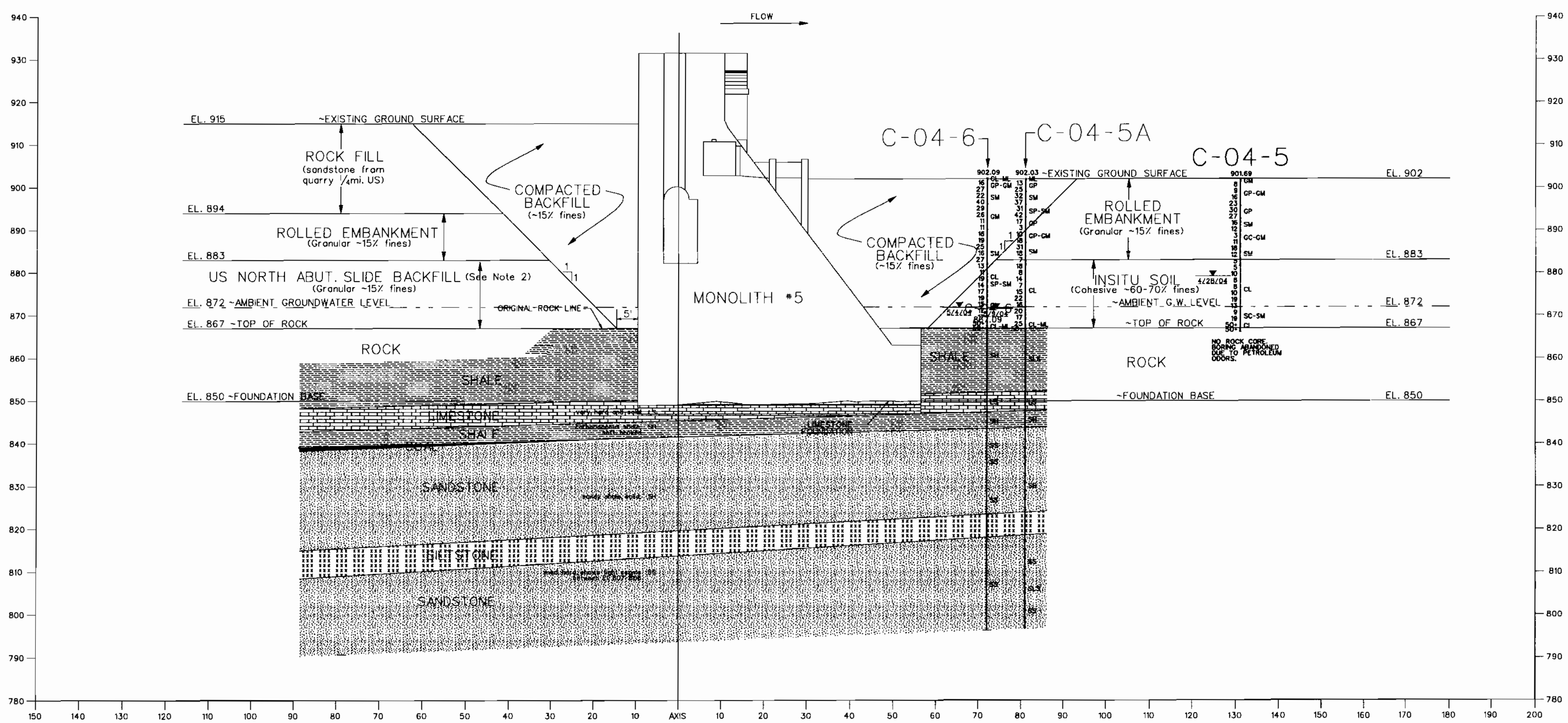
EXHIBIT II-5

OVERBURDEN SECTIONS



2004 BORING PLAN



MONOLITH #5 (M-5) - SECTION THRU STA. 3+26

OVERBURDEN

NOTES

1. Soil stratigraphies, as shown, and corresponding strength parameters were provided to CELRH-EC-DS (Structural Design Section) for use in stability analyses.

2. Construction Notes contained in the Dover Dam Periodic Inspection Report #1 state that due to a landslide in the right upstream abutment (following heavy rains) during construction, in situ soils were removed to bedrock and backfilled with rolled embankment. However, due to consistently lower blow counts (obtained during 2004 drilling) compared to average N-values for Rolled Embankment elsewhere at the project, this area was labeled as US North Abutment Backfill and given different soil parameters than Rolled Embankment.

US Army Corps of Engineers Huntington District

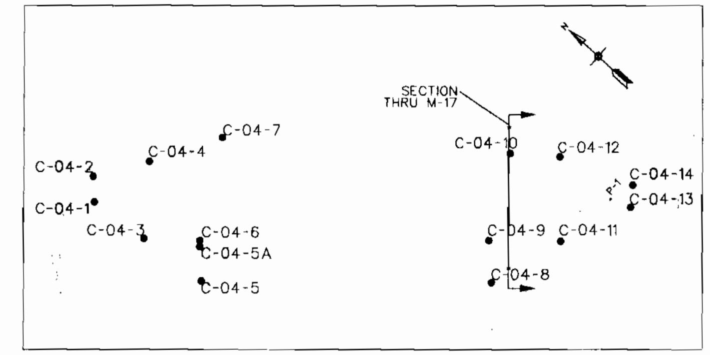
U.S. ARMY CORPS OF ENGINEERS

TUSCARAWAS RIVER
DOVER OH
DOVER DAM
DAM SAFETY ASSURANCE

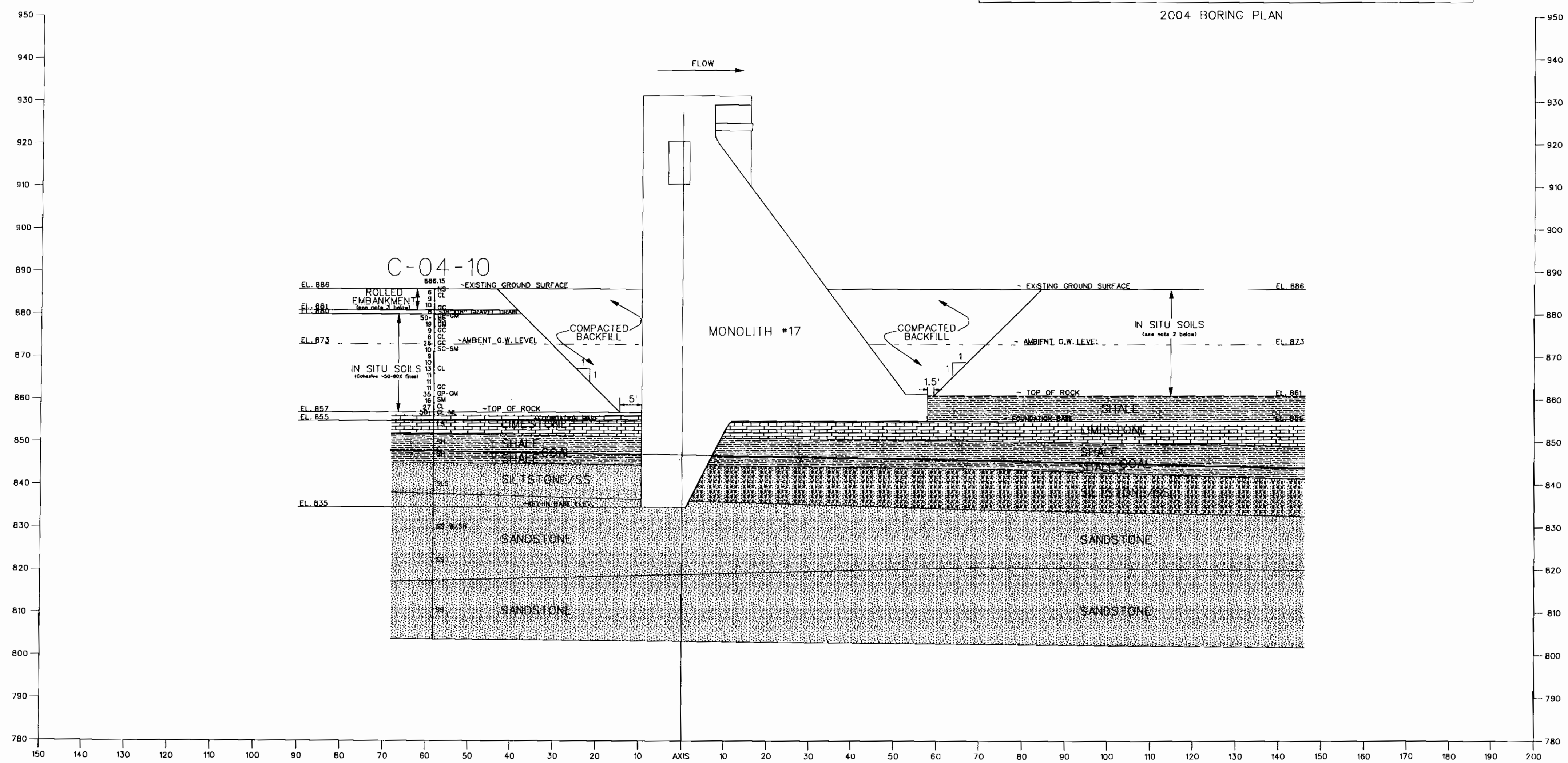
GEOTECHNICAL
RIGHT ABUTMENT OVERBURDEN
SECTION AT MONOLITH #5

Sheet reference number:
BI301
Sheet 1 of 1

EXHIBIT II-5



2004 BORING PLAN



MONOLITH #17 (M-17) - SECTION AT STA. 7+54
OVERBURDEN

NOTES

1. Soil stratigraphies, as shown, and corresponding strength parameters were provided to CELRH-EC-DS (Structural Design Section) for use in stability analyses.

2. Assumed same as upstream In Situ Soils (~50-60% fines) due to no available data from 2004 borings in dowstream left abutment (C-04-8, 9, & 11). Borings C-04-8 and C-04-9 are located in uncompacted backfill behind training/retaining wall and C-04-11 is located in uncompacted backfill adjacent to downstream side of dam.

3. Labeled as rolled embankment. However, this zone is not labeled so an as-built drawing. Assumed material is Uncompacted Backfill due to its soil classification (50% fines) and location (placed over In Situ Soils), as well as average blow count value (N=8), which is similar to Uncompacted Backfill elsewhere at the site. However, due to it's limited use on site, it was not included in the table of soil strength parameters (Table II-4). (See Tab II, Sec. 6.2.6)

US Army Corps of Engineers Huntington District

U.S. ARMY CORPS OF ENGINEERS
HUNTINGTON DISTRICT
HUNTINGTON, WEST VIRGINIA

TUSCARAWAS RIVER
DOVER, OH
DOVER DAM
DAM SAFETY ASSURANCE

GEOTECHNICAL
LEFT ABUTMENT OVERBURDEN
SECTION AT MONOLITH #17

Sheet reference number:
BI302
Sheet 1 of 1

EXHIBIT II-5

EXHIBIT II-6

ROCK LABORATORY TEST DATA

	Cross Bed Shear Intact Peak (ϕ) (c) psi	Shear Parallel to Bedding Natural Fracture Peak (ϕ) (c) psi	Basic phi angle Smooth Sawn Surface (ϕ) (c) psi	Bedrock Dam Interface Grout on Rock Peak (ϕ) (c) psi	AllowableBearing psi	E_{t50} Elastic Modulus (x10^6)	Unit Weight
Limestone	65 150 psi***	39 7 psi	29 0 psi	50 33 psi****	2191	24.740	168.5 pcf
Upper Sandstone	64 88 psi***	28 3 psi	26 0 psi	50 70 psi****	522	2.050	148 pcf
Sandy Siltstone	46 20 psi***	26 2 psi	21 0 psi	50 60 psi****	829	2.970	159.7 pcf
Siltstone	31 15 psi***	25 1.5 psi	14 0 psi	31 60 psi****	873	2.750	165.8 pcf
Shale	29 5 psi***	19 .5 psi	12.5 0 psi	30 50 psi****	300	1.750	161.5 pcf
Fault/Slickensided Joint*	19* 0 psi						
Concrete Key Lift Joint**		38 Controlled by Rebar**					

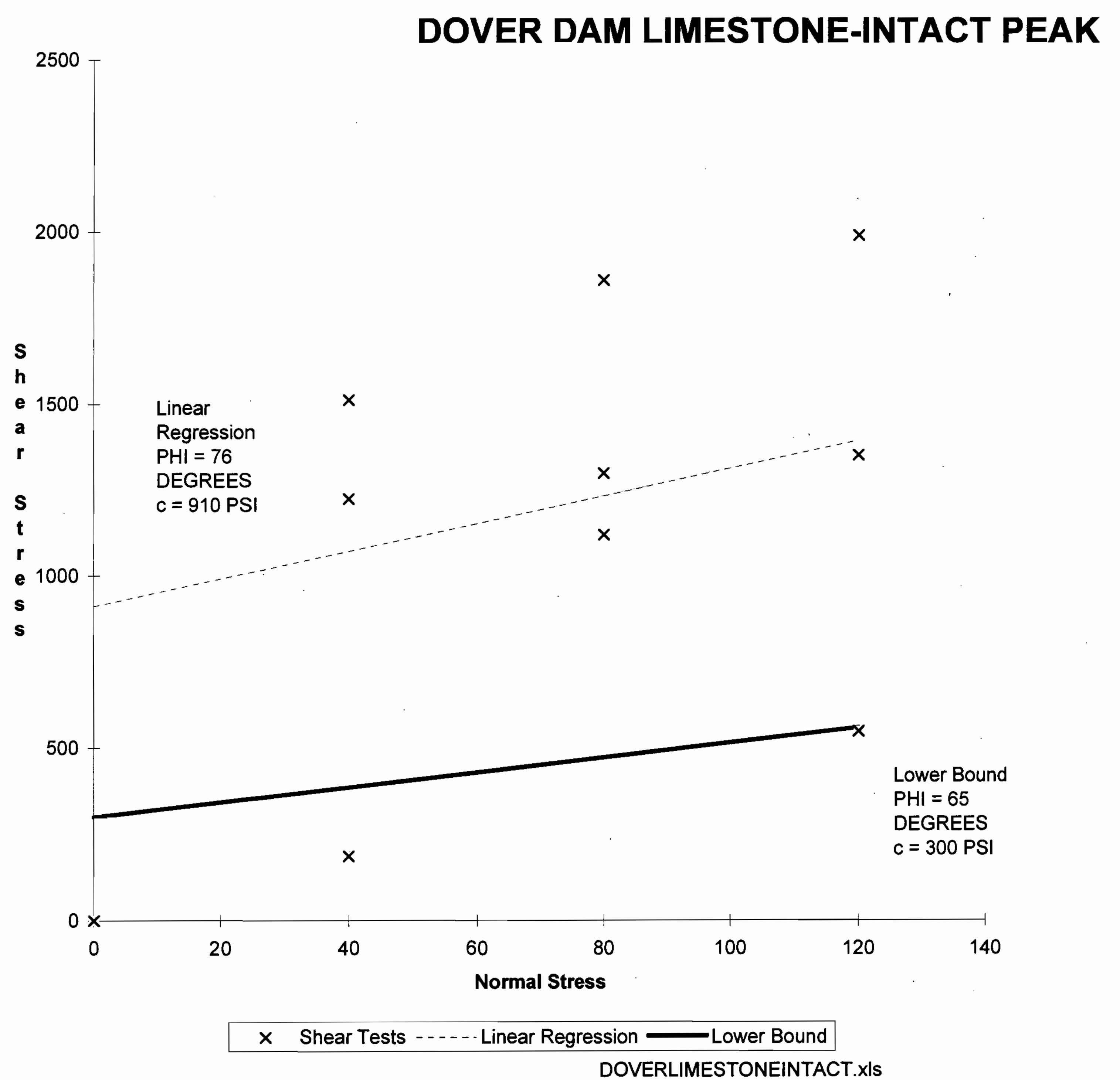
Shear Parallel to Bedding when used with the key should be reduced by 50% due to strain incompatibility with the rebar

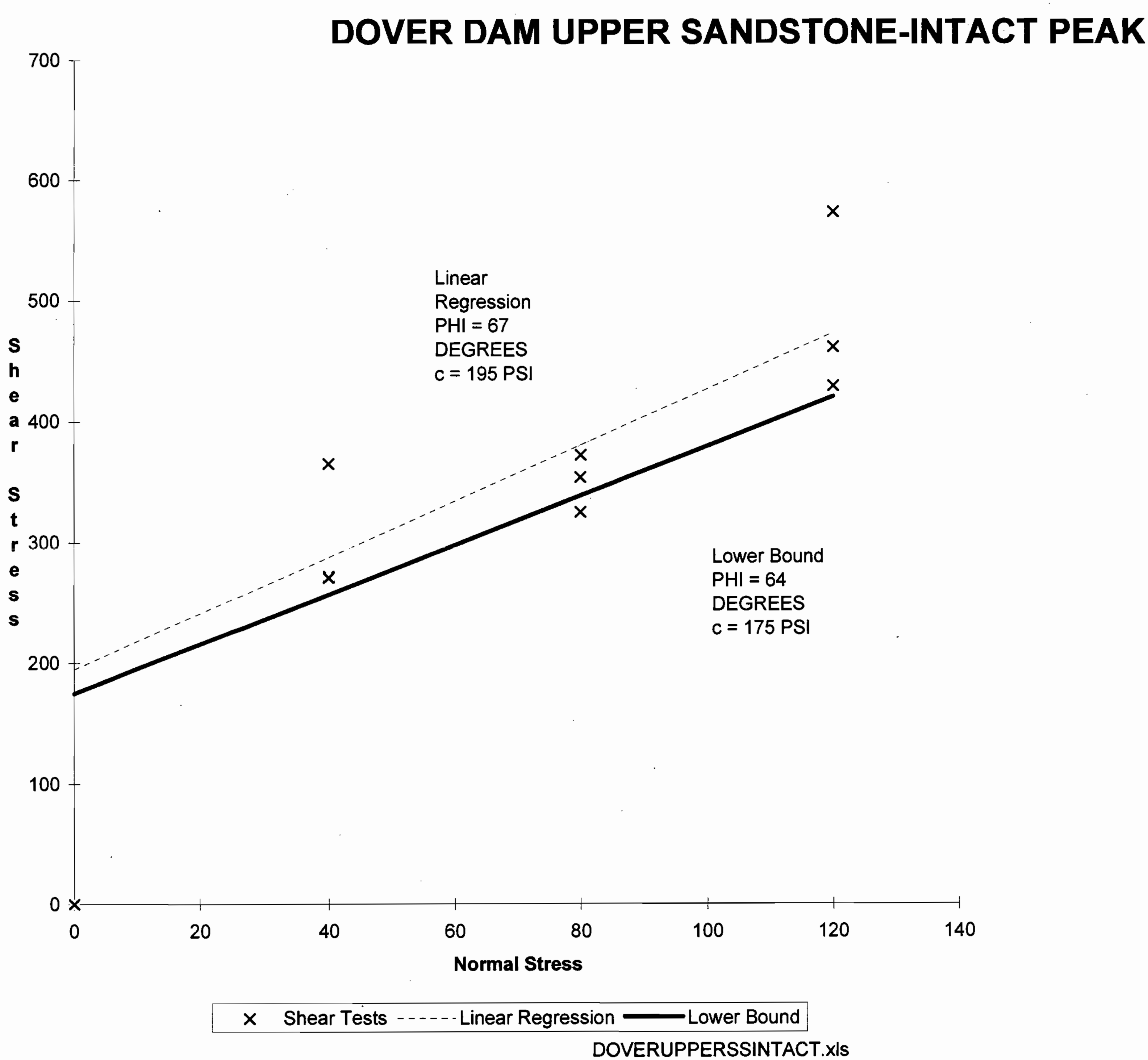
*The cross bed shear strength assigned to the (Fault / Slickensided Joint) is the average of the basic phi angle for all of the materials except the Upper Sandstone. The Upper Sandstone was excluded because it is not a component in the passive wedge of the 3 monoliths analyzed.

**The cohesion value used in the concrete key is assigned by structural section and is not published here.

***The cross bed shear cohesion was taken directly from the intact peak lower bound plot except cohesion was then reduced by 50 percent to account for scaling effects.

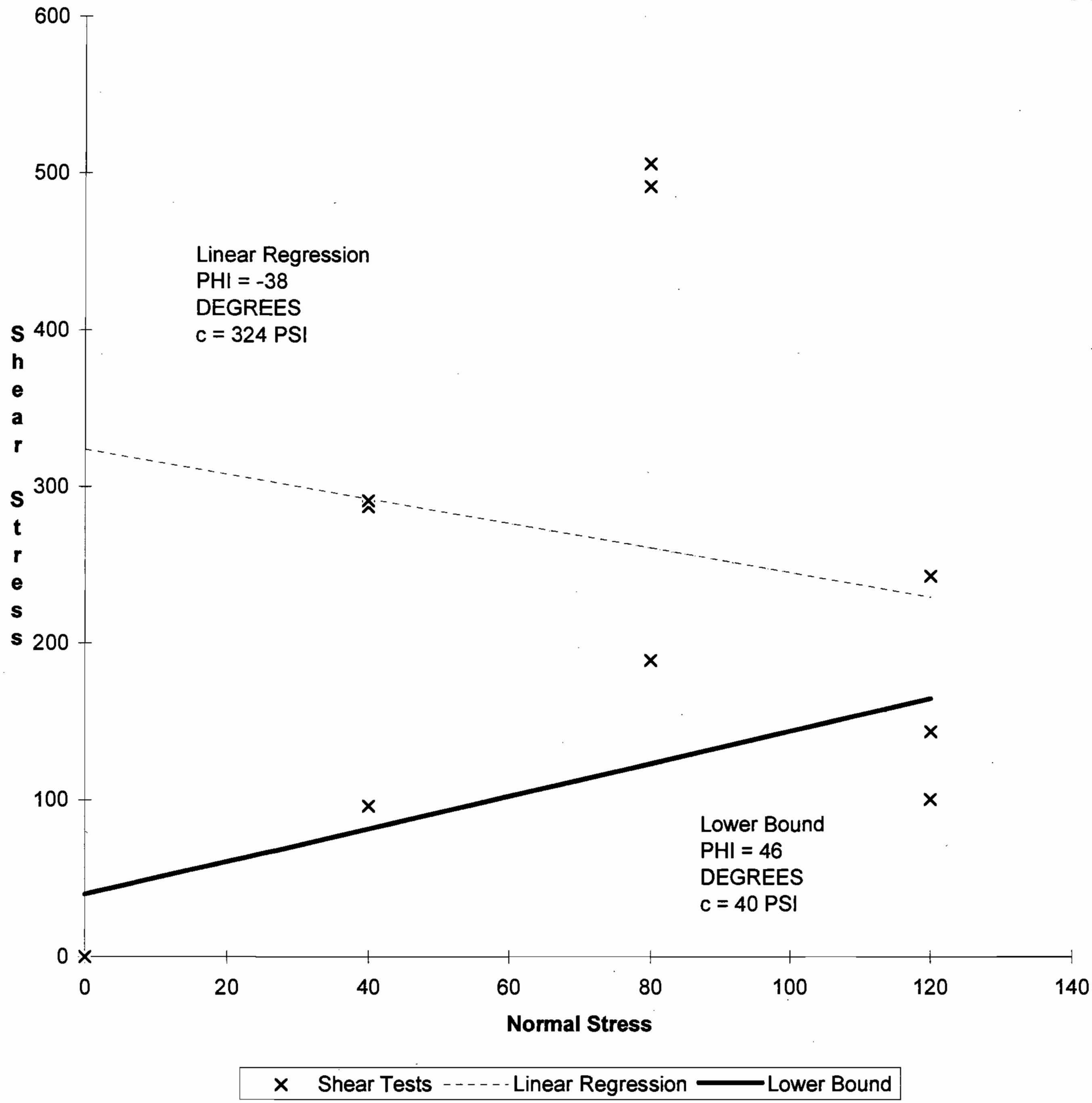
****The cohesion was taken directly from the lower bound plot of the grout on rock peak except cohesion was reduced by 66 percent to represent portions in the monolith where the contact is not bonded.


DOVER DAM LIMESTONE-INTACT PEAK
Shear Stress
Normal Stress
Linear Regression PHI = 76 DEGREES c = 910 PSI
Lower Bound PHI = 65 DEGREES c = 300 PSI
Shear Tests
Linear Regression
Lower Bound
0
500
1000
1500
2000
2500
20
40
60
80
100
120
140
DOVERLIMESTONEINTACT.xls



DOVER DAM UPPER SANDSTONE-INTACT PEAK
Shear Stress
700
600
500
400
300
200
100
0
Linear
Regression
PHI = 67
DEGREES
c = 195 PSI
Lower Bound
PHI = 64
DEGREES
c = 175 PSI
0
20
40
60
80
100
120
140
Normal Stress
Shear Tests
Linear Regression
Lower Bound
DOVERUPPERSSINTACT.xls

DOVER DAM SANDY SILTSTONE-INTACT PEAK



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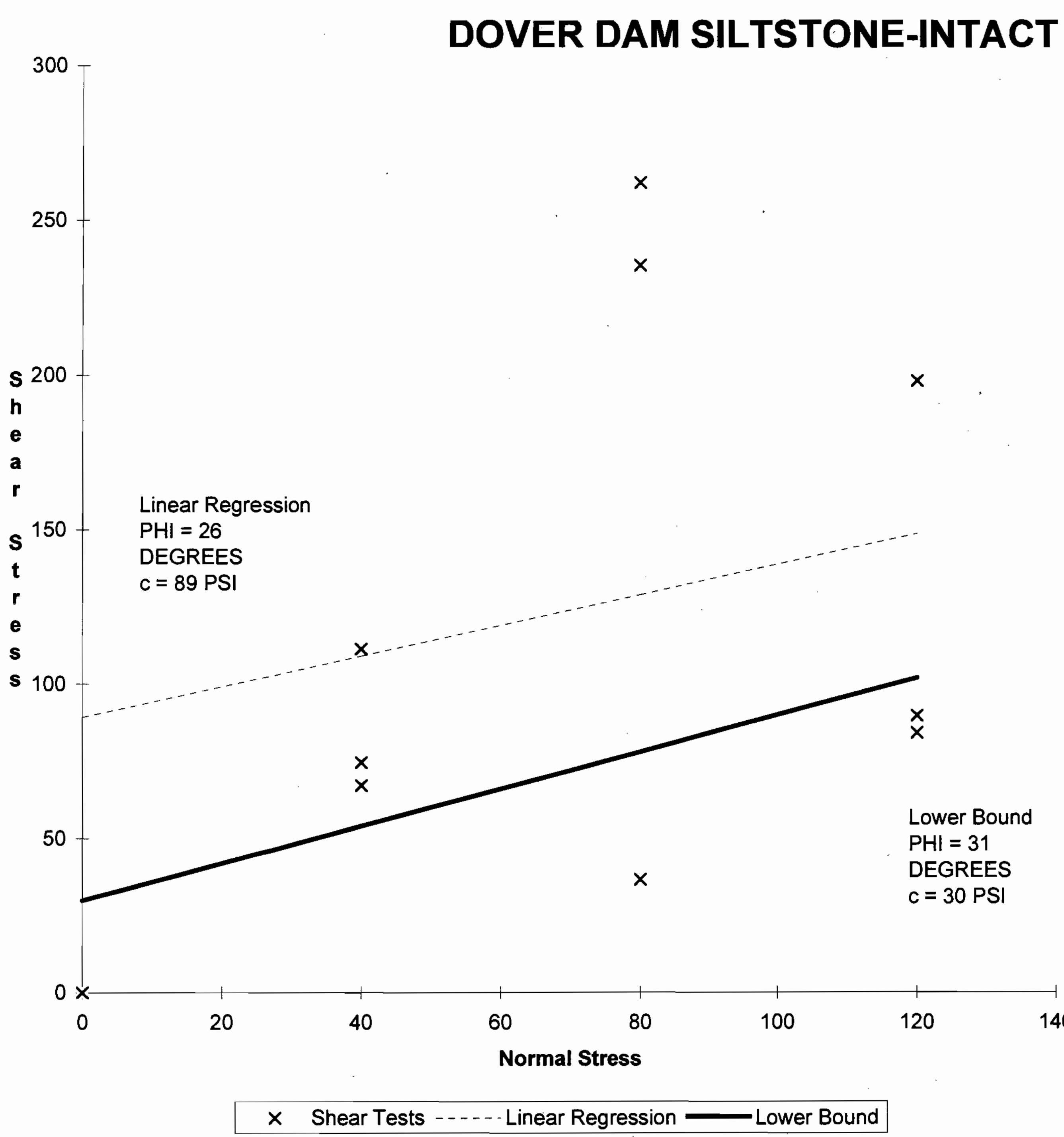

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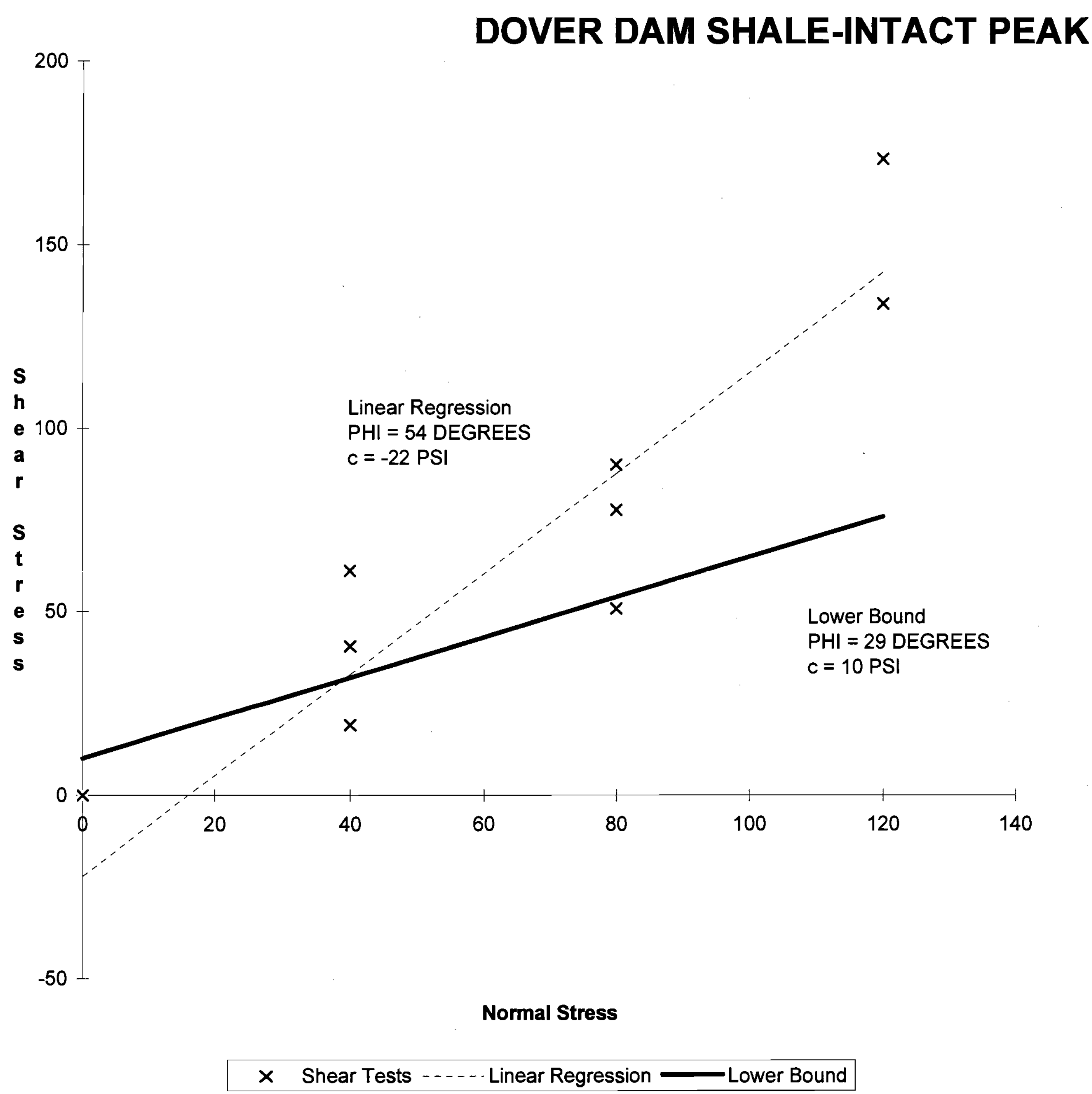


DOVERSHALEINTACT.xls

Summary of Rock Testing Results
Direct Shear of Intact Rock Specimens

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Limestone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DS-103	1	C-04-03	82.7	40.0	1,224.4	32.2[(1)]
				80.0		74.5
				120.0		109.9
DS-104	2	C-04-03	85.1	80.0	1,120.2	99.5
				40.0		41.8
				120.0		128.5
DS-105	3	C-04-06	51.7	120.0	1,991.0	58.4[(1)]
				40.0		15.4
				80.0		29.7
DS-106	4	C-04-06	52.3	40.0	1,513.2	22.0[(1)]
				80.0		55.4
				120.0		83.5
DS-107	5	C-04-06	53.0	80.0	1,860.6	81.8[(1)]
				40.0		39.1
				120.0		113.9
DS-108	6	C-04-05A	54.2	120.0	1,351.1	122.1
				40.0		41.1
				80.0		82.8
DS-109	7	C-04-13	50.3	40.0	186.0	54.3
				80.0		77.6
				120.0		100.2
DS-110	8	C-04-09	31.2	80.0	1,298.8	30.0[(1)]
				40.0		18.0
				120.0		50.3
DS-111	9	C-04-09	34.3	120.0	546.8	140.1
				40.0		50.3
				80.0		84.9

Note(s): (1). Shear plane extended in Hydro-stone encasement and additional preparation was performed prior to additional shearing.

Summary of Rock Testing Results
Direct Shear of Intact Rock Specimens

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Upper Sandstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DS-76	1	C-04-01	13.5	40.0	272.1	15.2(1)
				80.0		30.9
				120.0		47.9
DS-77	2	C-04-01	14.2	80.0	354.3	79.4
				40.0		35.5
				120.0		112.7
DS-78	3	C-04-01	16.1	120.0	574.1	99.5
				40.0		40.0
				80.0		64.0
DS-79	4	C-04-01	43.1	40.0	365.2	42.5
				80.0		67.5
				120.0		91.0
DS-80	5	C-04-01	45.3	80.0	372.7	78.5
				40.0		28.6
				120.0		93.2
DS-81	6	C-04-14	32.1	120.0	461.9	130.6
				40.0		42.3
				80.0		76.8
DS-82	7	C-04-14	35.9	40.0	271.0	55.1
				80.0		63.5(2)
				120.0		85.5
DS-83	8	C-04-14	38.5	80.0	325.2	117.0
				40.0		47.0
				120.0		129.8
DS-84	9	C-04-13	41.2	120.0	429.7	109.2
				40.0		35.9
				80.0		70.4

Note(s): (1). Shear plane extended in Hydro-stone encasement and additional preparation was performed prior to additional shearing.
(2). Equipment malfunction caused premature termination of second test.

Summary of Rock Testing Results
Direct Shear of Intact Rock Specimens

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone / Sandy

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DS-85	1	C-04-06	59.2	40.0	96.4	38.5
				80.0		71.9
				120.0		92.5
DS-86	2	C-04-06	63.1	80.0	189.2	47.0
				40.0		26.8
				120.0		67.3
DS-87	3	C-04-06	70.7	120.0	100.4	67.0
				40.0		25.3
				80.0		44.0
DS-88	4	C-04-06	90.5	40.0	287.5	38.0
				80.0		67.5
				120.0		90.0
DS-89	5	C-04-06	98.3	80.0	506.2	139.9
				40.0		N/A(1)
				120.0		N/A(1)
DS-90	6	C-04-09	52.8	120.0	243.1	77.6
				40.0		24.7
				80.0		45.5
DS-91	7	C-04-09	53.75	40.0	291.4	23.8
				80.0		41.6
				120.0		66.5
DS-92	8	C-04-09	57.7	80.0	492.1	49.5(2)
				40.0		20.4
				120.0		63.5
DS-93	9	C-04-09	67.6	120.0	143.6	63.2
				40.0		17.0
				80.0		30.8

Note(s): (1). Specimen deteriorated during initial test, prohibiting additional tests.
(2). Shear plane extended in Hydro-stone encasement and additional preparation was performed prior to additional shearing.

Summary of Rock Testing Results
Direct Shear of Intact Rock Specimens

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DS-112	1	C-04-04	96.1	40.0	74.6	30.7
				80.0		53.6
				120.0		71.1
DS-113	2	C-04-04	96.6	80.0	262.2	81.4
				40.0		44.3
				120.0		116.3
DS-114	3	C-04-04	97.0	120.0	89.6	N/A(1)
				40.0		24.9
				80.0		46.9
DS-115	4	C-04-06	79.1	40.0	67.1	30.2
				80.0		50.9
				120.0		70.2
DS-116	5	C-04-06	82.5	80.0	235.5	52.1
				40.0		21.3
				120.0		N/A(2)
DS-117	6	C-04-05A	80.5	120.0	84.1	70.1
				40.0		22.0
				80.0		40.5
DS-118	7	C-04-05A	82.0	40.0	111.4	32.4
				80.0		50.1
				120.0		62.8
DS-119	8	C-04-09	49.7	80.0	36.7	24.6
				40.0		11.6
				120.0		29.6
DS-120	9	C-04-10	43.3	120.0	198.2	90.6
				40.0		19.3
				80.0		44.0

Note(s): (1). Stable sliding resistance not achieved in 0.5-inch deflection.
(2). Specimen deteriorated during second test, prohibiting additional tests.

Summary of Rock Testing Results
Direct Shear of Intact Rock Specimens

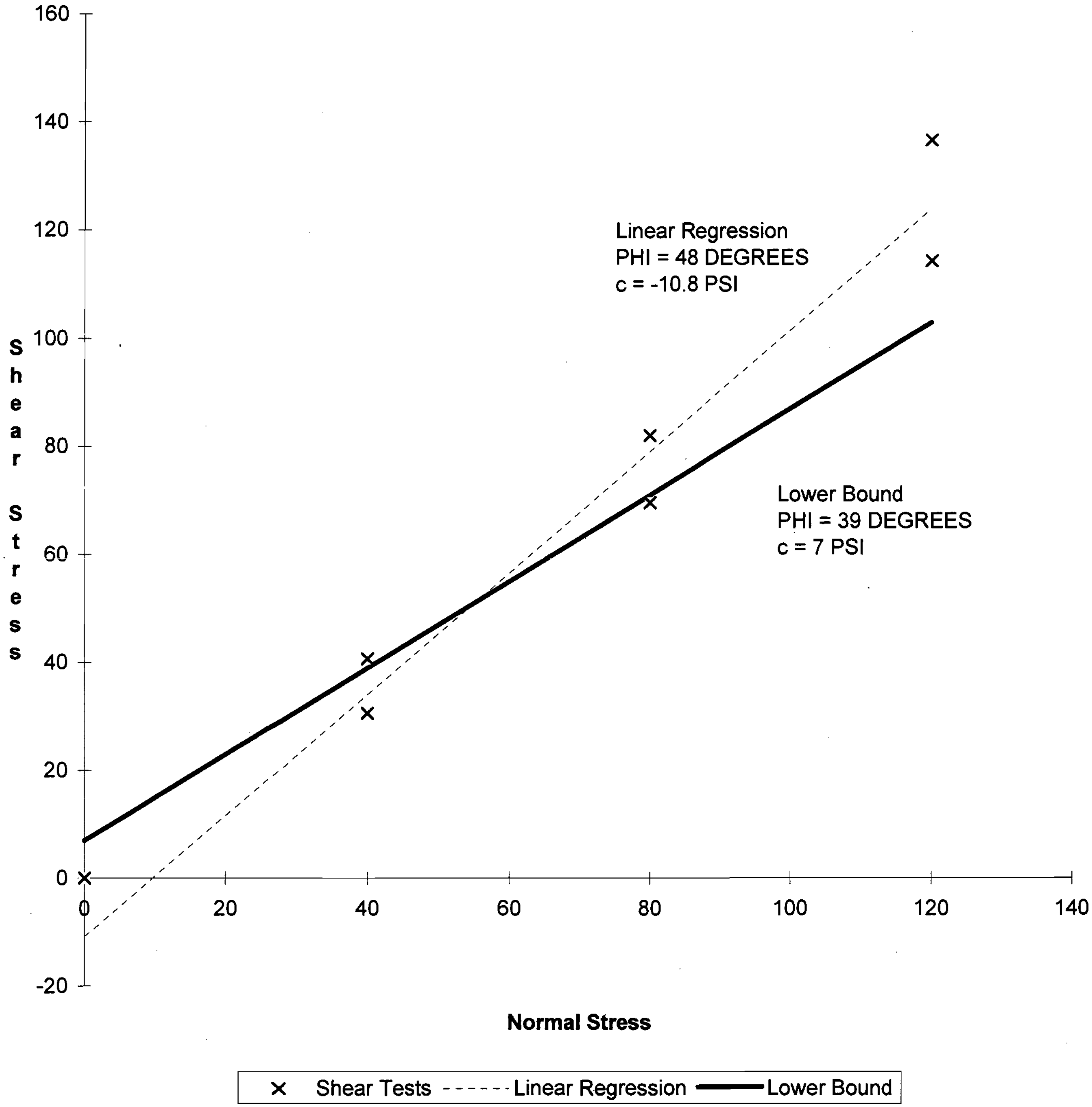
Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Shale

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DS-94	1	C-04-01	62.0	40.0	40.6	21.8
				80.0		34.1
				120.0		52.2
DS-95	2	C-04-01	68.7	80.0	77.8	50.1
				40.0		21.4
				120.0		72.8
DS-96	3	C-04-01	71.0	120.0	173.4	69.7
				40.0		23.6
				80.0		40.6
DS-97	4	C-04-13	46.0	40.0	61.1	36.8(1)
				80.0		42.4(1)
				120.0		25.4(1)
DS-98	5	C-04-13	47.5	80.0	50.8	30.7
				40.0		15.7
				120.0		39.3
DS-99	6	C-04-13	48.2	120.0	1,916.5	N/A(2)
				40.0		N/A(2)
				80.0		N/A(2)
DS-100	7	C-04-13	48.4	40.0	19.1	16.8(1)
				80.0		34.1(1)
				120.0		N/A(3)
DS-101	8	C-04-13	91.0	80.0	90.2	71.7
				40.0		34.4
				120.0		80.6
DS-102	9	C-04-13	92.9	120.0	134.1	58.1
				40.0		16.5
				80.0		30.3

Note(s): (1). Specimen shear surfaces deteriorated with each test.
(2). Specimen deteriorated during initial test, prohibiting additional tests.
(3). Stable sliding resistance not achieved in 0.5-inch deflection.

DOVER DAM LIMESTONE-NATURAL FRACTURE PEAK



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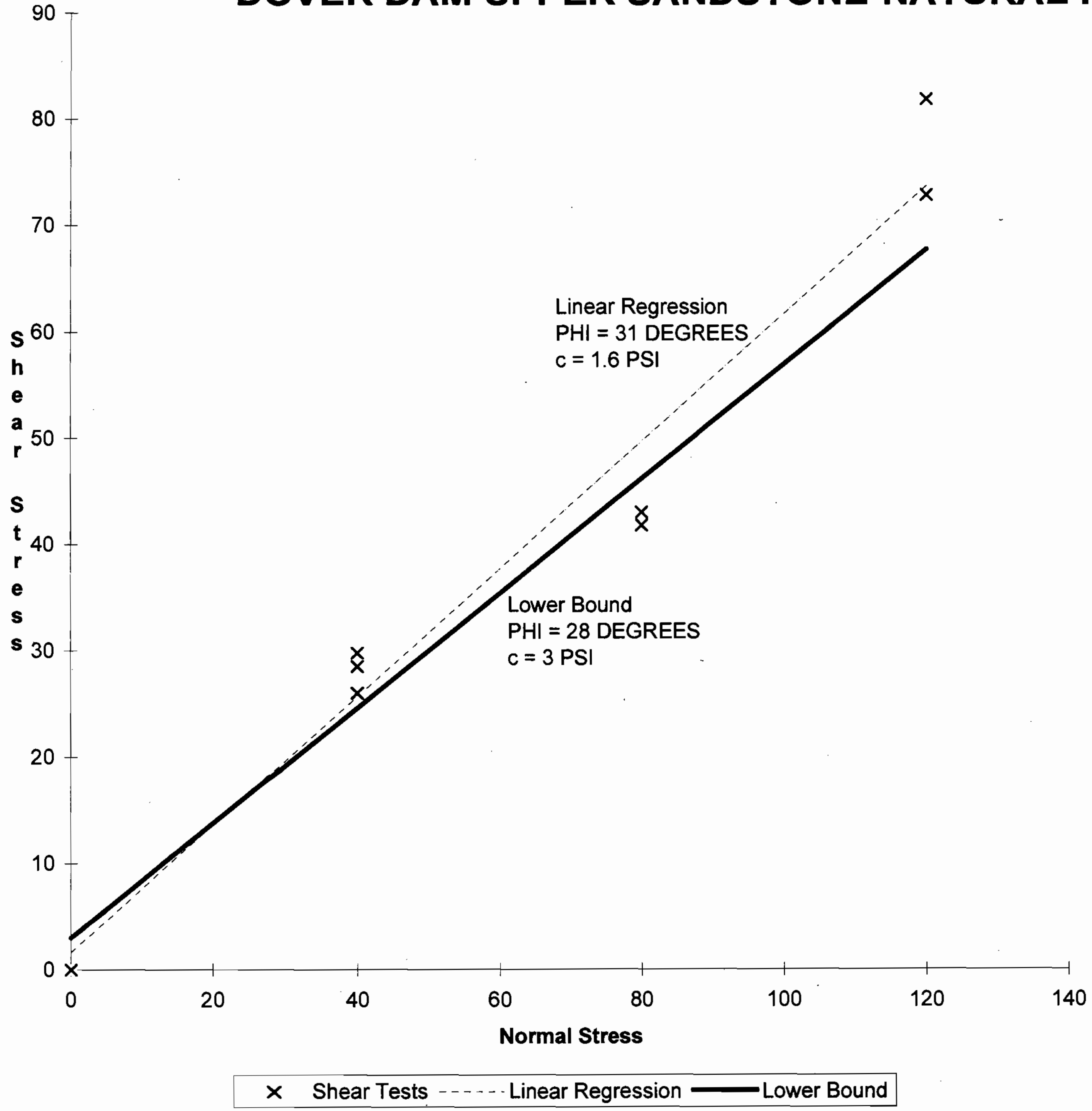
DOVER DAM UPPER SANDSTONE-NATURAL FRACTURE PEAK



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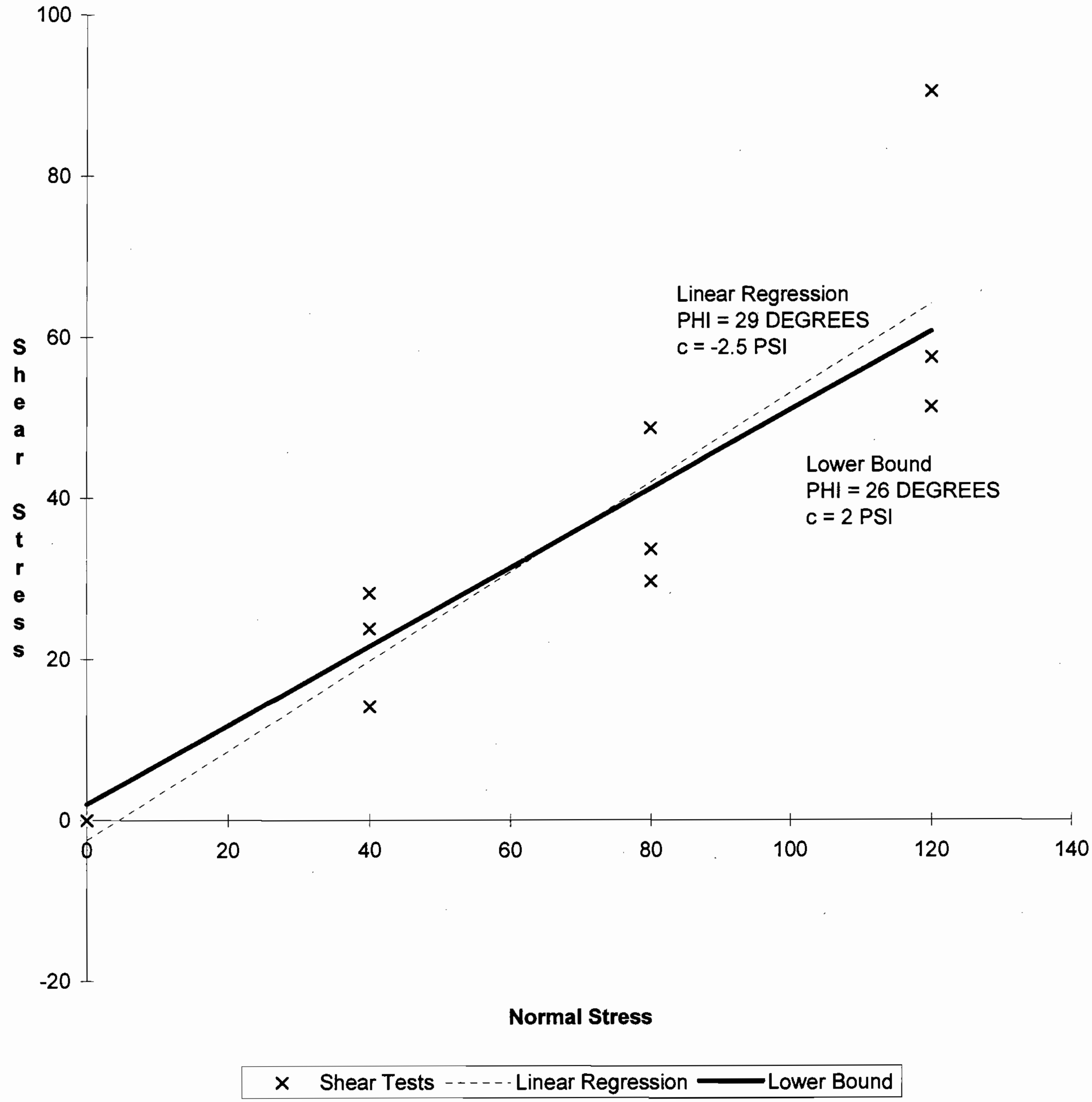
DOVER DAM SANDY SILTSTONE-NATURAL FRACTURE PEAK



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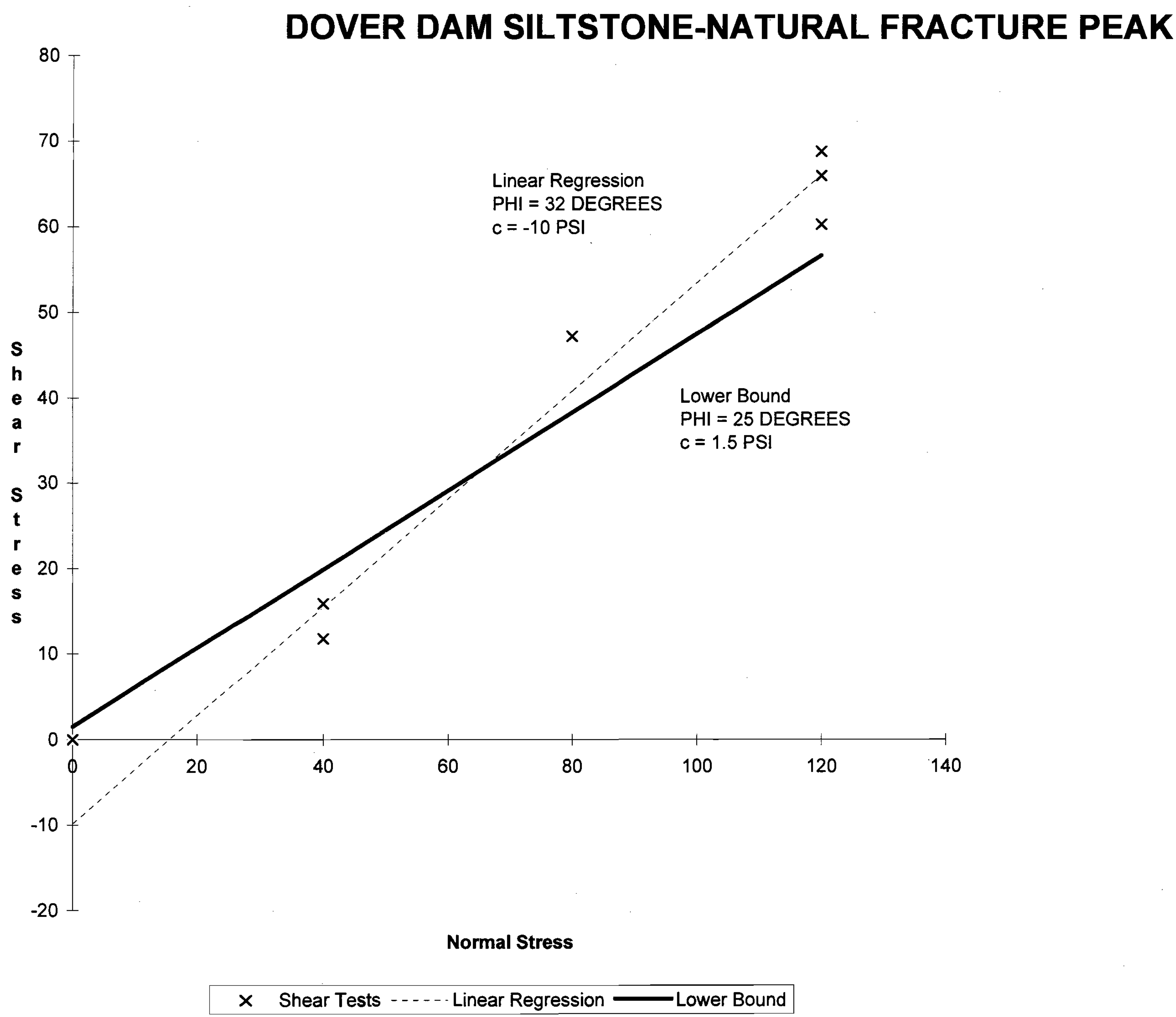

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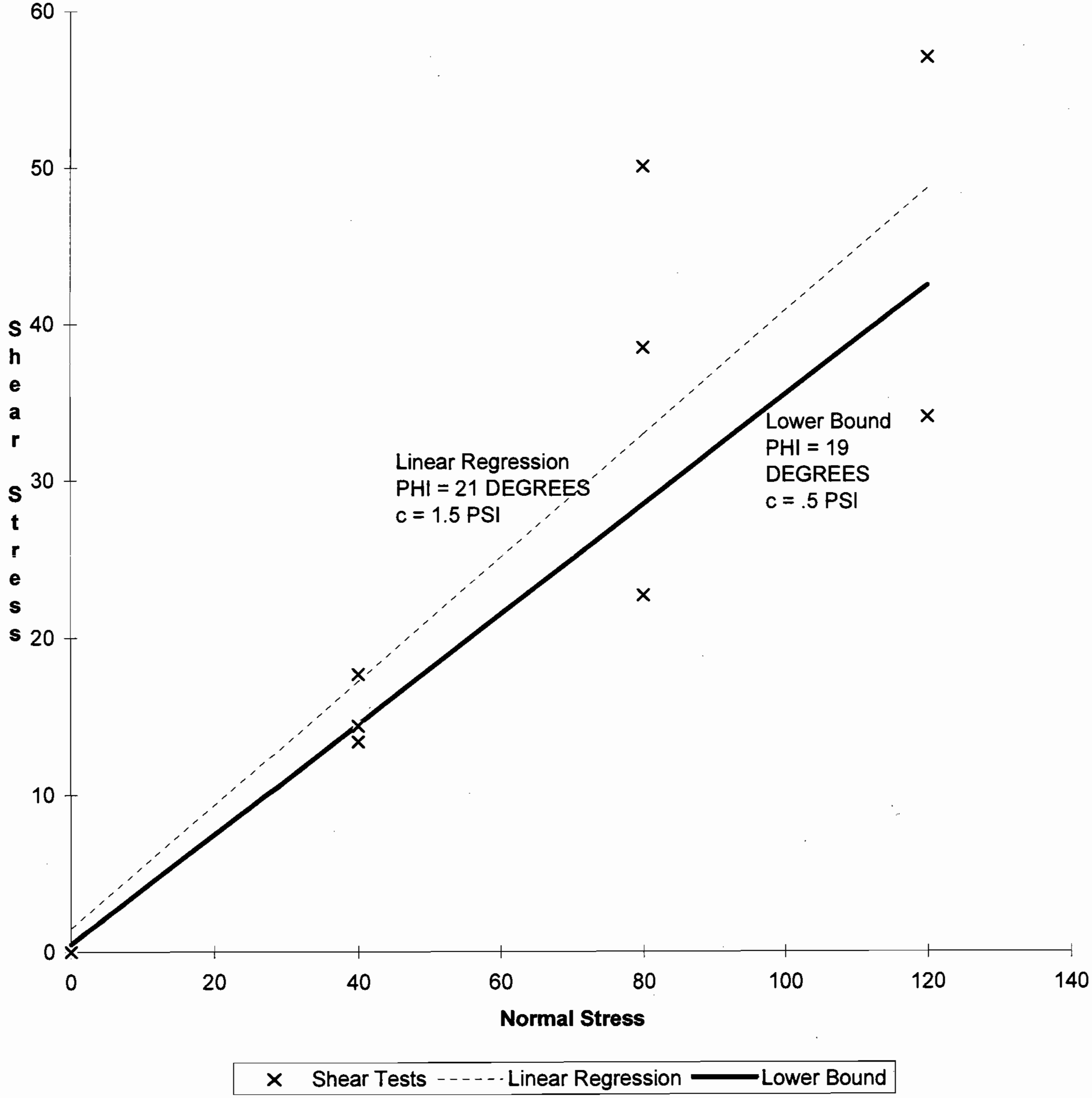
DOVER DAM SHALE-NATURAL FRACTURE PEAK



DOVERSHALENF.xls

Summary of Rock Testing Results
Direct Shear of Natural Rock Fractures

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Limestone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSNF-28	1	C-04-03	84.2	40.0	40.7	30.1
				80.0		56.7
				120.0		82.0
DSNF-29	2	C-04-06	50.3	80.0	82.0	50.9
				40.0		29.3
				120.0		84.7
DSNF-30	3	C-04-06	53.4	120.0	114.3	80.4
				40.0		30.3
				80.0		61.1
DSNF-31	4	C-04-11	20.2	40.0	30.6	26.2
				80.0		47.5
				120.0		71.2
DSNF-32	5	C-04-02	64.6	80.0	69.6	62.6
				40.0		33.0
				120.0		93.4
DSNF-33	6	C-04-14	83.7	120.0	136.7	91.8
				40.0		33.8
				80.0		60.7

Summary of Rock Testing Results
Direct Shear of Natural Rock Fractures

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Upper Sandstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSNF-1	1	C-04-01	17.2	40.0	29.8	24.1
				80.0		42.0
				120.0		60.1
DSNF-2	2	C-04-01	17.8	80.0	43.0	34.5
				40.0		16.0
				120.0		48.3
DSNF-3	3	C-04-01	19.0	120.0	72.9	62.5
				40.0		22.9
				80.0		44.6
DSNF-4	4	C-04-01	22.5	40.0	26.0	24.2
				80.0		45.2
				120.0		64.8
DSNF-5	5	C-04-01	40.9	80.0	N/A(1)	52.5
				40.0		25.8
				120.0		N/A(2)
DSNF-6	6	C-04-14	34.6	120.0	81.9	70.7
				40.0		26.3
				80.0		48.5
DSNF-7	7	C-04-14	37.1	40.0	28.5	24.2
				80.0		45.6
				120.0		65.3
DSNF-8	8	C-04-14	39.0	80.0	41.8	38.0
				40.0		21.7
				120.0		58.1
DSNF-9	9	C-04-14	40.5	120.0	N/A(1)	58.3
				40.0		20.6
				80.0		38.2

Note(s): (1). No apparent peak shear stress was observed for initial test.
(2). Stable sliding resistance not achieved in 0.5-inch deflection.

Summary of Rock Testing Results
Direct Shear of Natural Rock Fractures

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone / Sandy

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSNF-10	1	C-04-06	60.8	40.0	28.2	18.9
				80.0		31.1
				120.0		37.5
DSNF-11	2	C-04-06	64.5	80.0	48.7	31.9
				40.0		N/A(1)
				120.0		N/A(1)
DSNF-12	3	C-04-06	65.2	120.0	57.5	51.3
				40.0		14.2
				80.0		24.5
DSNF-13	4	C-04-06	67.9	40.0	14.1	13.6
				80.0		N/A(2)
				120.0		N/A(2)
DSNF-14	5	C-04-06	67.3	80.0	33.7	27.6
				40.0		12.4
				120.0		36.5
DSNF-15	6	C-04-06	91.0	120.0	51.4	49.8
				40.0		16.8
				80.0		31.4
DSNF-16	7	C-04-09	52.0	40.0	23.8	20.1
				80.0		33.5
				120.0		47.3
DSNF-17	8	C-04-09	62.6	80.0	29.7	26.7
				40.0		11.0
				120.0		N/A(2)
DSNF-18	9	C-04-09	65.1	120.0	90.6	76.4
				40.0		27.9
				80.0		48.5

Note(s): (1). Specimen deteriorated during initial test, prohibiting additional tests.
(2). Stable sliding resistance not achieved in 0.5-inch deflection.

Summary of Rock Testing Results
Direct Shear of Natural Rock Fractures

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSNF-37	1	C-04-04	98.2	40.0	11.8	10.9
				80.0		15.5
				120.0		22.5
DSNF-38	2	C-04-06	81.7	80.0	N/A(1)	37.1
				40.0		19.4
				120.0		54.0
DSNF-39	3	C-04-05A	81.3	120.0	68.8	43.5
				40.0		19.6
				80.0		32.6
DSNF-40	4	C-04-10	42.9	40.0	15.9	14.1
				80.0		26.4
				120.0		31.7
DSNF-41	5	C-04-10	45.4	80.0	47.2	30.1
				40.0		16.2
				120.0		39.2
DSNF-42	6	C-04-07	71.8	120.0	66.0	50.4
				40.0		17.6
				80.0		32.0
DSNF-43	7	C-04-07	73.1	40.0	N/A(1)	14.0
				80.0		26.3
				120.0		37.0
DSNF-44	8	C-04-07	73.5	80.0	N/A(1)	26.0
				40.0		15.4
				120.0		36.7
DSNF-45	9	C-04-07	74.9	120.0	60.3	47.7
				40.0		17.1
				80.0		30.6

Note(s): (1). No apparent peak shear stress was observed for initial test.

Summary of Rock Testing Results
Direct Shear of Natural Rock Fractures

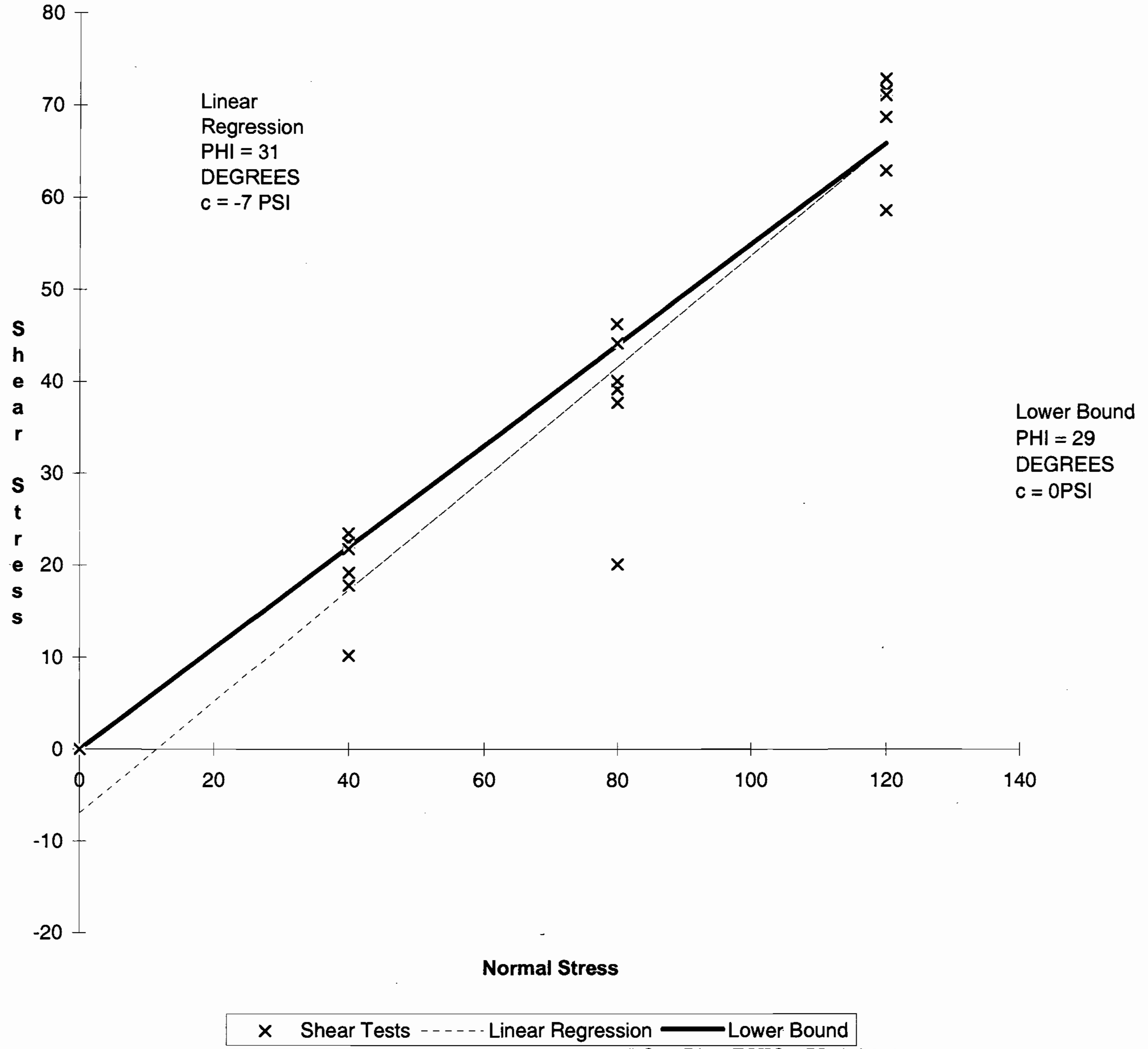
Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Shale

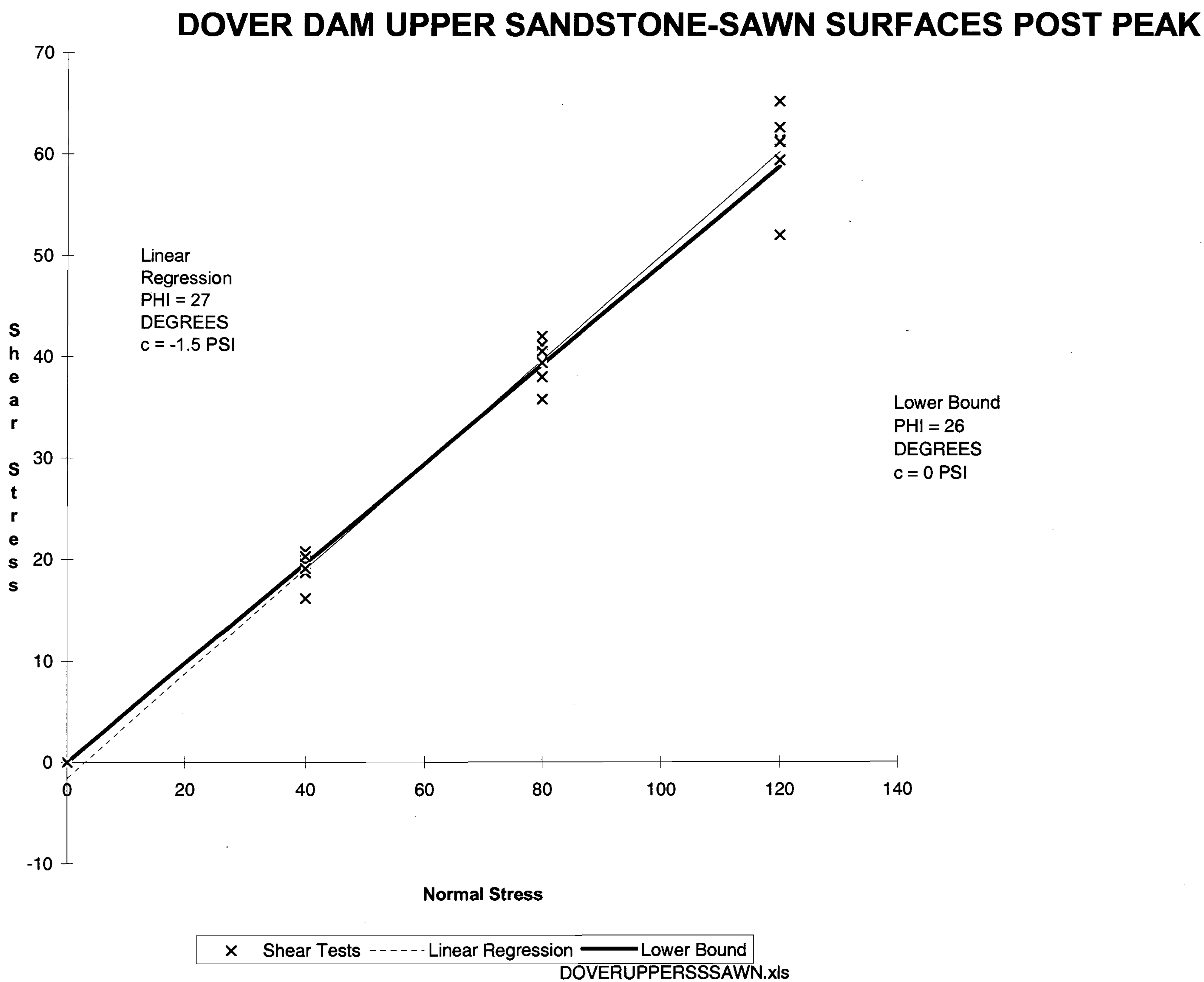
FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSNF-19	1	C-04-01	59.6	40.0	17.7	16.5
				80.0		N/A(1)
				120.0		N/A(1)
DSNF-20	2	C-04-01	68.0	80.0	50.1	30.1
				40.0		19.0
				120.0		36.7
DSNF-21	3	C-04-01	69.5	120.0	57.1	49.0
				40.0		15.4
				80.0		24.3
DSNF-22	4	C-04-13	46.9	40.0	13.4	12.9
				80.0		19.6
				120.0		28.3
DSNF-23	5	C-04-13	47.8	80.0	22.7	17.5
				40.0		11.2
				120.0		27.6
DSNF-24	6	C-04-13	86.5	120.0	34.1	32.1
				40.0		9.7
				80.0		18.1
DSNF-25	7	C-04-13	88.5	40.0	14.4	12.3
				80.0		17.6
				120.0		29.3
DSNF-26	8	C-04-06	43.1	80.0	38.5	30.1
				40.0		15.0
				120.0		44.3
DSNF-27	9	C-04-06	43.8	120.0	N/A(2)	N/A(3)
				40.0		14.4
				80.0		21.6

Note(s): (1). Specimen deteriorated during initial test, prohibiting additional tests.
(2). No apparent peak shear stress was observed for initial test.
(3). Stable sliding resistance not achieved in 0.5-inch deflection.

DOVER DAM LIMESTONE-SAWN SURFACES POST PEAK



DOVERLIMESTONESAWN.xls


DOVER DAM UPPER SANDSTONE-SAWN SURFACES POST PEAK
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Regression
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DEGREES
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Lower Bound
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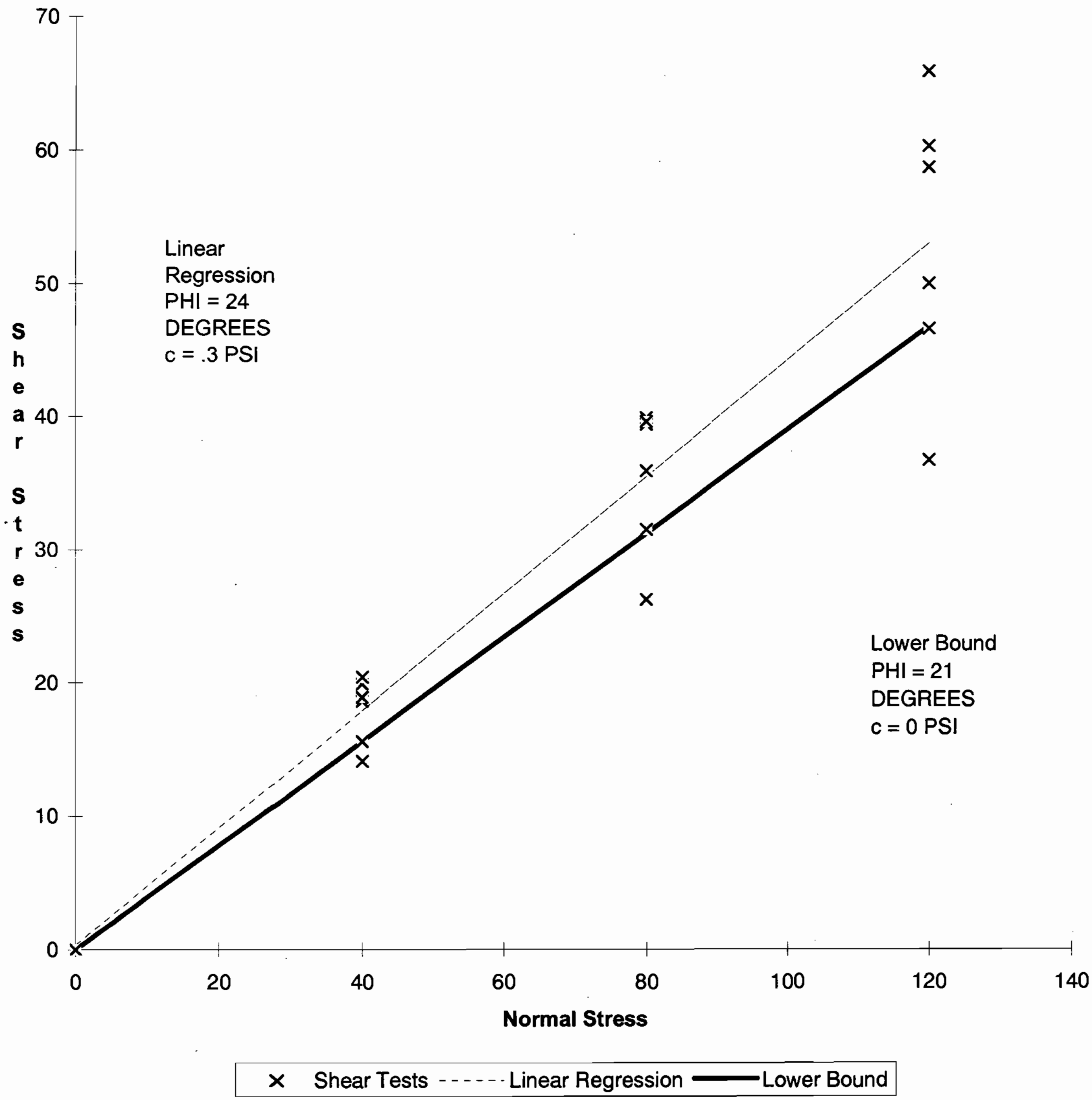
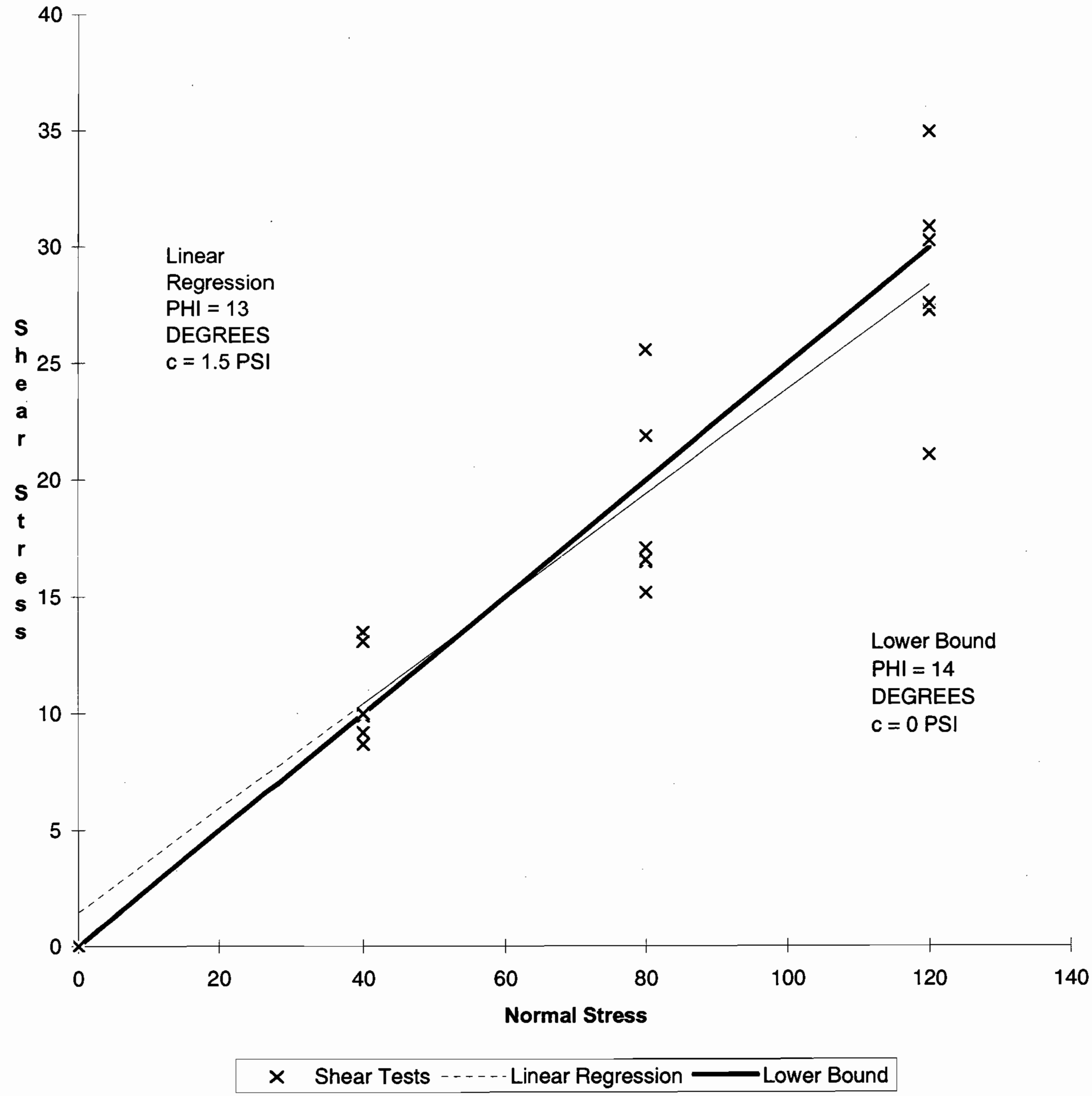
DEGREES
c = 0 PSI
Shear Stress
Normal Stress
70
60
50
40
30
20
10
0
-10
0
20
40
60
80
100
120
140
Shear Tests
Linear Regression
Lower Bound
DOVERUPPERSSSAWN.xls

DOVER DAM SANDY SILTSTONE-SAWN SURFACES POST PEAK



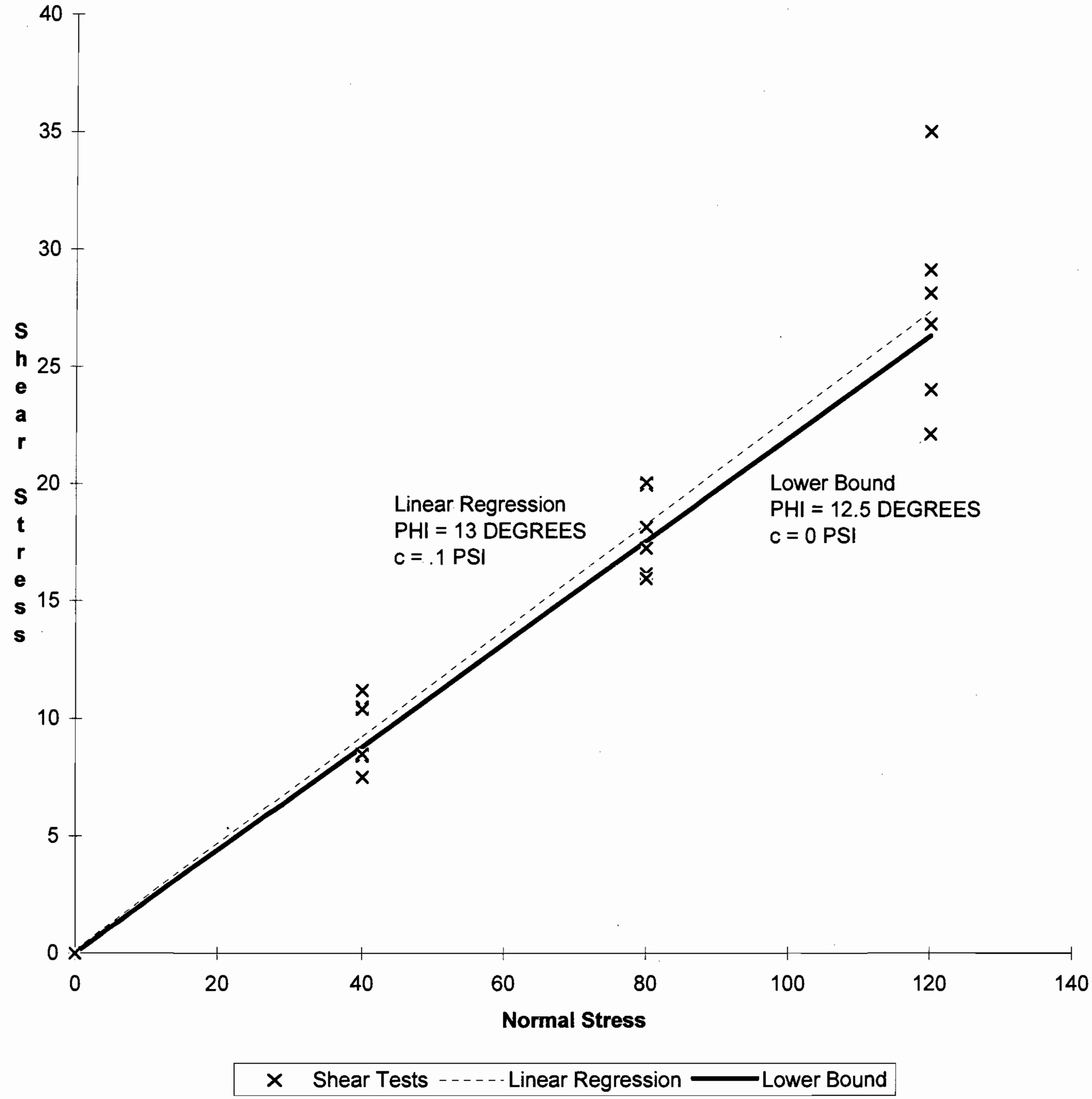
DOVERSANDYSILTSTONESAWN.xls

DOVER DAM SILTSTONE-SAWN SURFACES POST PEAK



DOVERSILTSTONESAWN.xls

DOVER DAM SHALE-SAWN SURFACES POST PEAK



DOVERSHALESAWN.xls

Summary of Rock Testing Results
Direct Shear of Rock-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Limestone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSSS-64	1	C-04-05A	50.8	40.0	N/A(1)	22.5
				80.0		46.3
				120.0		71.7
DSSS-65	2	C-04-05A	51.4	80.0	N/A(1)	39.2
				40.0		19.2
				120.0		58.7
DSSS-66	3	C-04-05A	53.7	120.0	N/A(1)	68.8
				40.0		10.2
				80.0		20.1
DSSS-67	4	C-04-09	31.7	40.0	N/A(1)	21.8
				80.0		40.1
				120.0		71.2
DSSS-68	5	C-04-09	33.6	80.0	N/A(1)	44.2
				40.0		23.5
				120.0		73.0
DSSS-69	6	C-04-13	80.2	120.0	N/A(1)	63.0
				40.0		17.8
				80.0		37.7

Note(s): (1). No apparent peak shear stress was observed for initial test.

Summary of Rock Testing Results
Direct Shear of Rock-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Upper Sandstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSSS-46	1	C-04-01	19.8	40.0	N/A(1)	20.8
				80.0		42.0
				120.0		61.4
DSSS-47	2	C-04-01	21.7	80.0	N/A(1)	41.1
				40.0		19.6
				120.0		61.2
DSSS-48	3	C-04-01	41.6	120.0	N/A(1)	59.4
				40.0		18.7
				80.0		38.0
DSSS-49	4	C-04-14	22.4	40.0	N/A(1)	16.2
				80.0		35.8
				120.0		52.0
DSSS-50	5	C-04-13	37.9	80.0	N/A(1)	40.5
				40.0		20.3
				120.0		62.6
DSSS-51	6	C-04-13	39.2	120.0	N/A(1)	65.2
				40.0		19.1
				80.0		39.4

Note(s): (1). No apparent peak shear stress was observed for initial test.

Summary of Rock Testing Results
Direct Shear of Rock-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone / Sandy

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSSS-52	1	C-04-06	62.2	40.0	17.0	14.1
				80.0		26.2
				120.0		36.7
DSSS-53	2	C-04-06	69.7	80.0	38.3	35.9
				40.0		18.6
				120.0		50.0
DSSS-54	3	C-04-06	92.0	120.0	N/A(1)	65.9
				40.0		19.9
				80.0		39.9
DSSS-55	4	C-04-09	50.9	40.0	17.2	15.6
				80.0		31.5
				120.0		46.6
DSSS-56	5	C-04-09	68.9	80.0	N/A(1)	39.4
				40.0		18.9
				120.0		58.7
DSSS-57	6	C-04-09	71.5	120.0	61.2	60.3
				40.0		20.4
				80.0		39.6

Note(s): (1). No apparent peak shear stress was observed for initial test.

Summary of Rock Testing Results
Direct Shear of Rock-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSSS-70	1	C-04-04	97.4	40.0	18.6	13.5
				80.0		25.6
				120.0		30.9
DSSS-71	2	C-04-04	98.8	80.0	26.1	16.5
				40.0		9.9
				120.0		27.3
DSSS-72	3	C-04-06	80.3	120.0	41.2	30.3
				40.0		10.0
				80.0		16.6
DSSS-73	4	C-04-06	83.3	40.0	N/A(1)	13.1
				80.0		21.9
				120.0		35.0
DSSS-74	5	C-04-05A	80.9	80.0	24.9	17.1
				40.0		9.2
				120.0		21.1
DSSS-75	6	C-04-10	47.9	120.0	39.7	27.6
				40.0		8.7
				80.0		15.2

Note(s): (1). No apparent peak shear stress was observed for initial test.

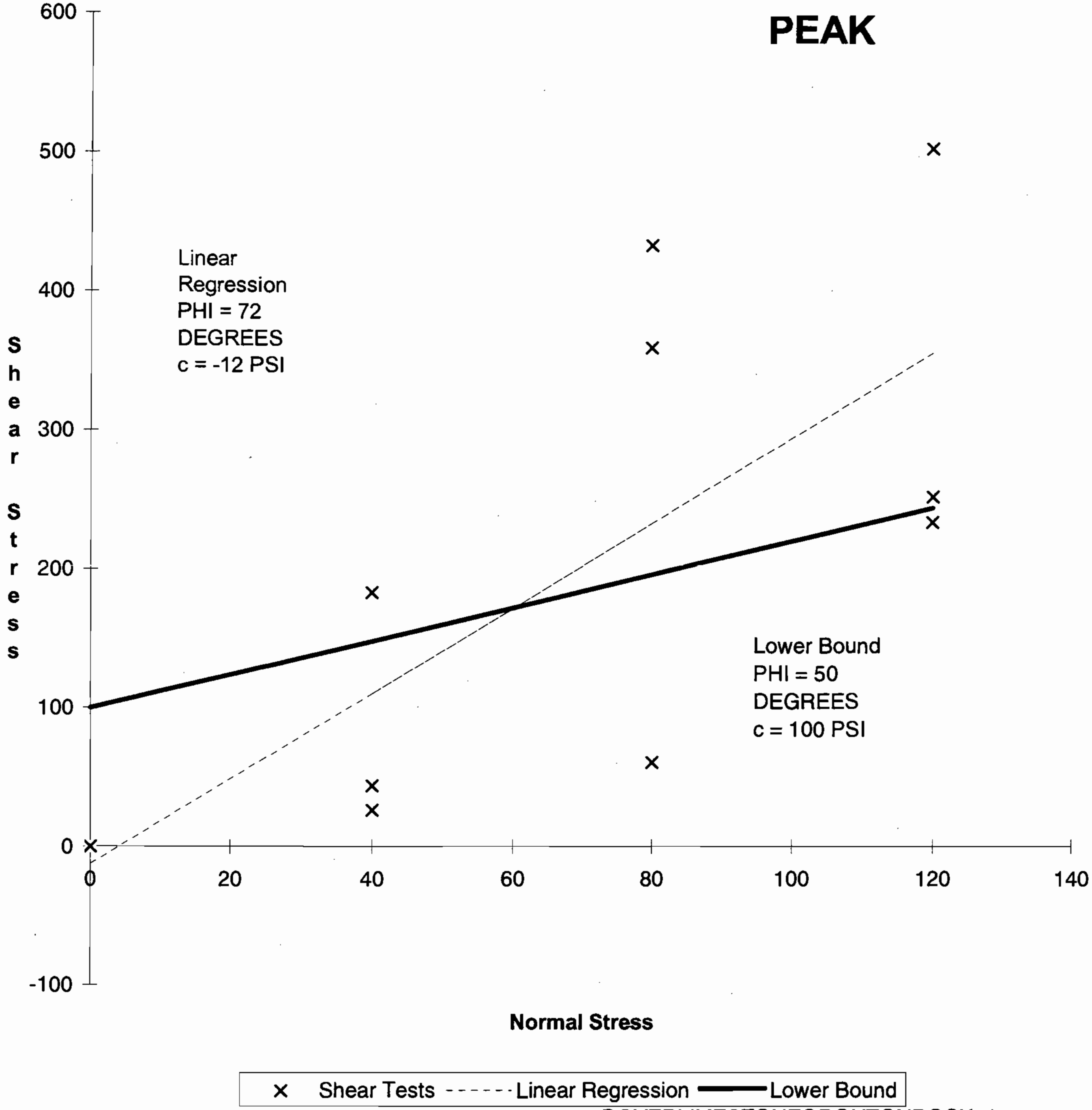
Summary of Rock Testing Results
Direct Shear of Rock-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Shale

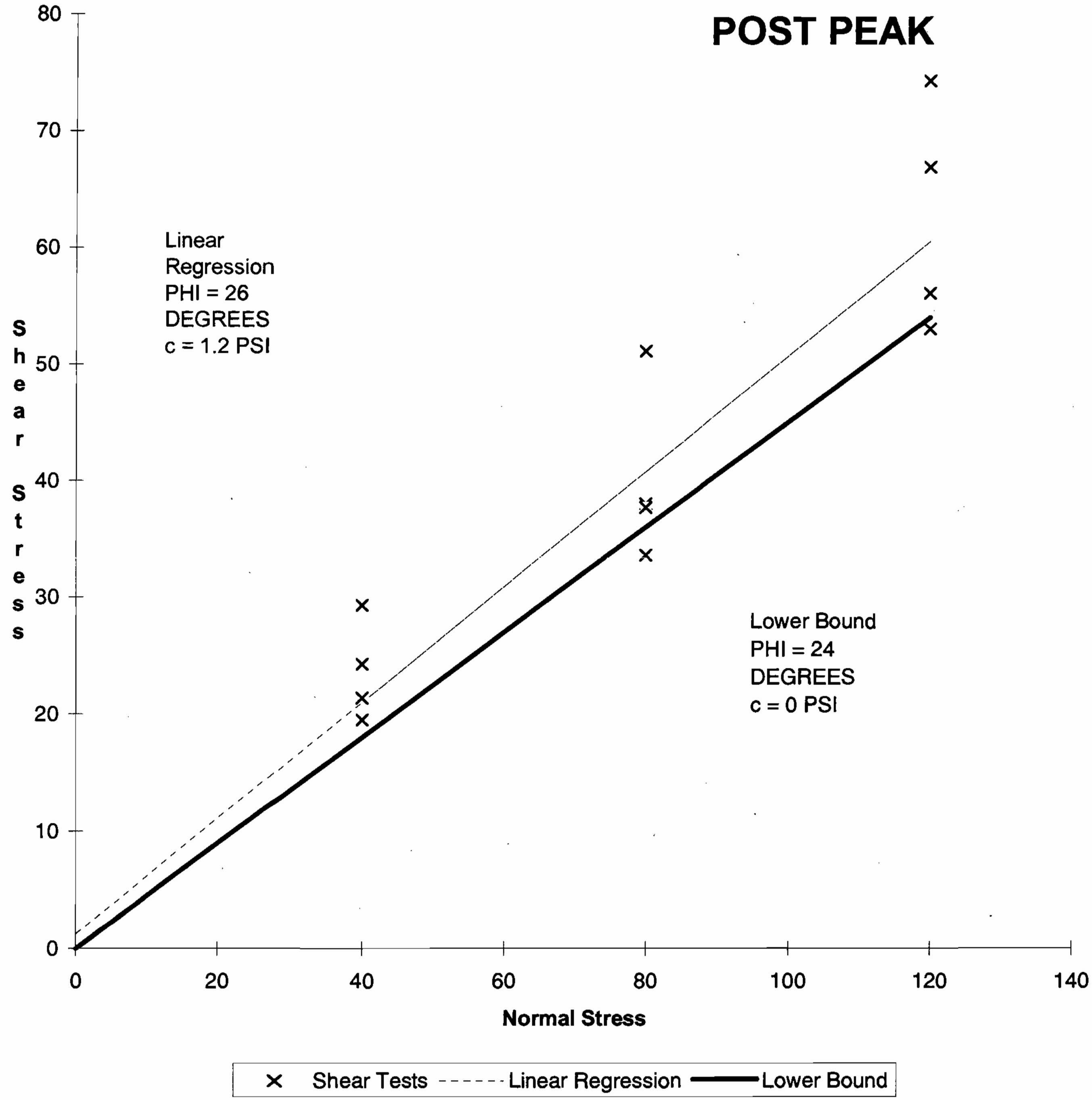
FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSSS-58	1	C-04-06	44.6	40.0	13.8	10.5
				80.0		17.3
				120.0		26.9
DSSS-59	2	C-04-05A	43.0	80.0	28.9	20.0
				40.0		10.4
				120.0		29.2
DSSS-60	3	C-04-05A	43.8	120.0	39.4	28.2
				40.0		8.4
				80.0		16.2
DSSS-61	4	C-04-05A	44.2	40.0	13.5	8.5
				80.0		16.0
				120.0		24.1
DSSS-62	5	C-04-05A	45.3	80.0	26.1	18.2
				40.0		7.5
				120.0		22.2
DSSS-63	6	C-04-05A	45.7	120.0	47.7	35.1
				40.0		11.2
				80.0		20.1

DOVER DAM LIMESTONE-GROUT-ON-ROCK SAWN SURFACES PEAK



DOVERLIMESTONEGROUTONROCK.xls

DOVER DAM LIMESTONE-GROUT-ON-ROCK SAWN SURFACES POST PEAK



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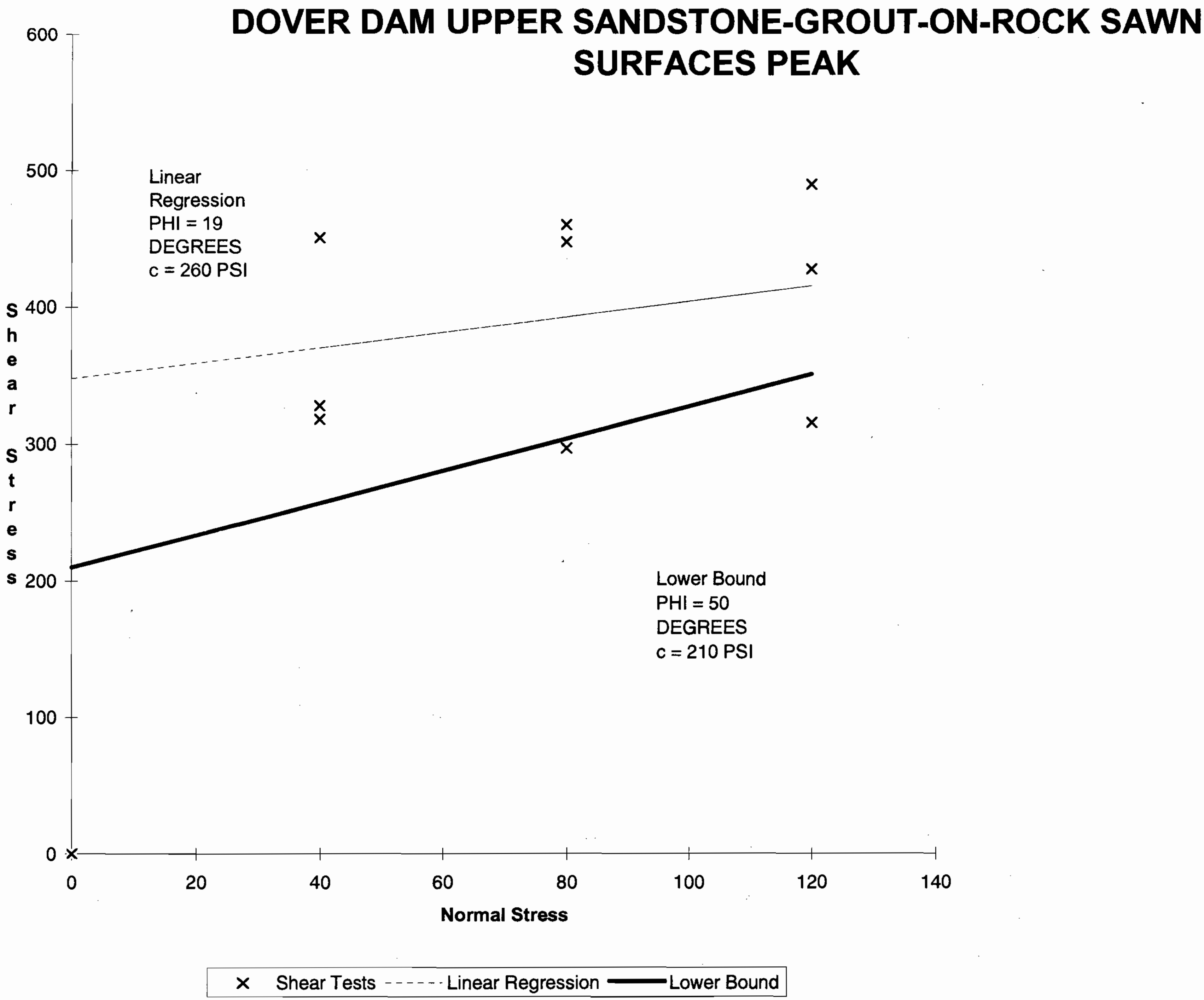

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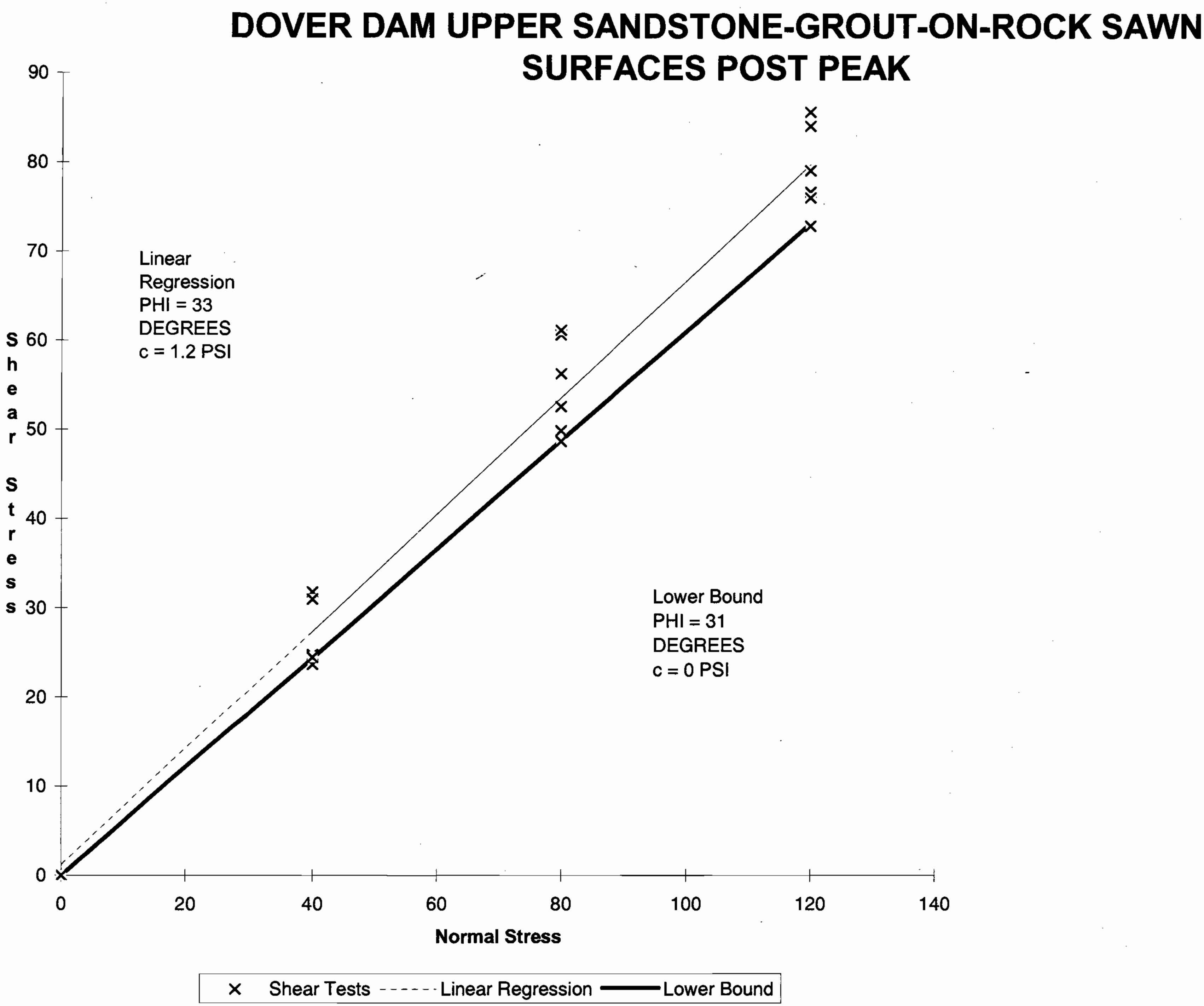

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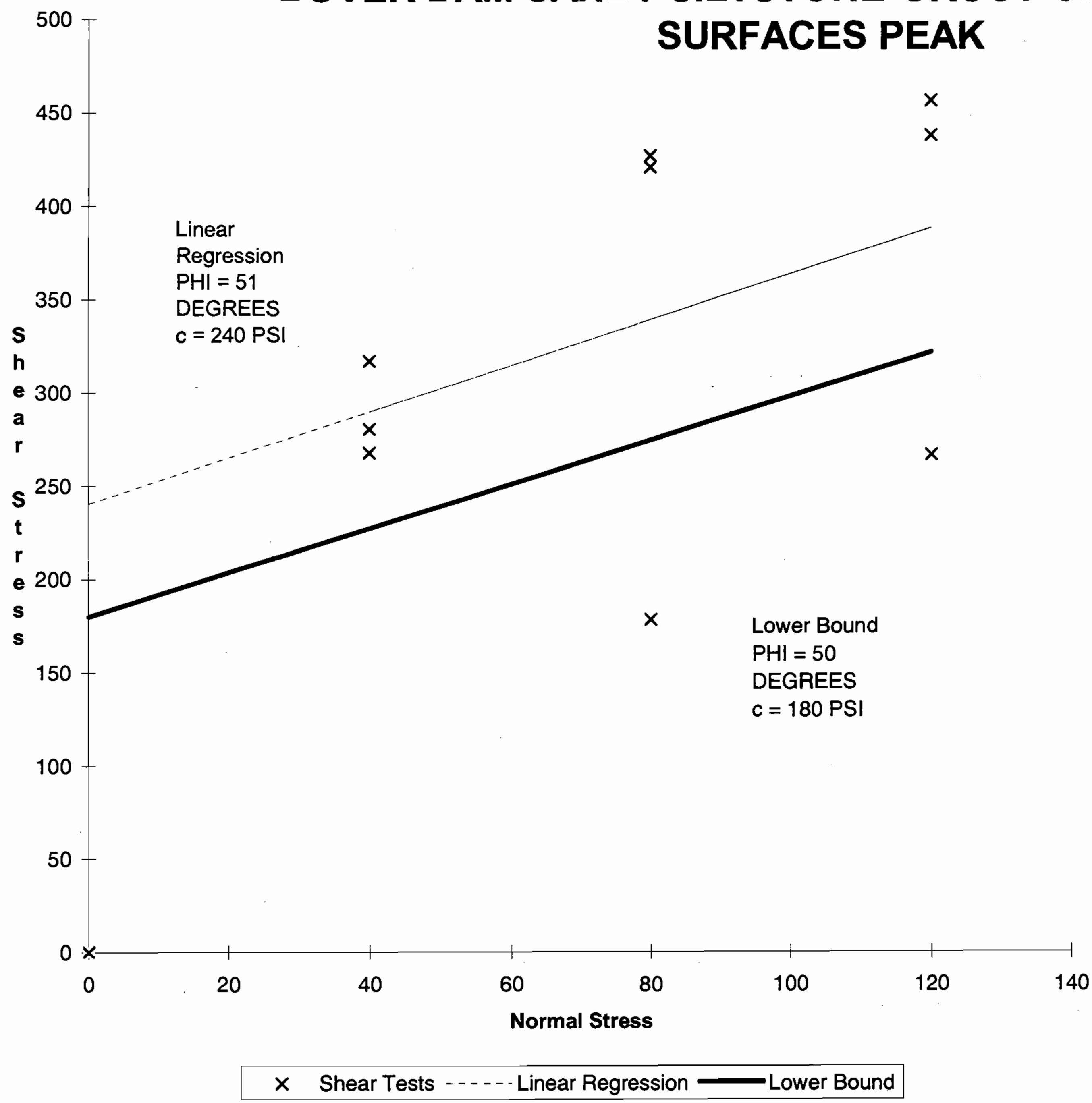
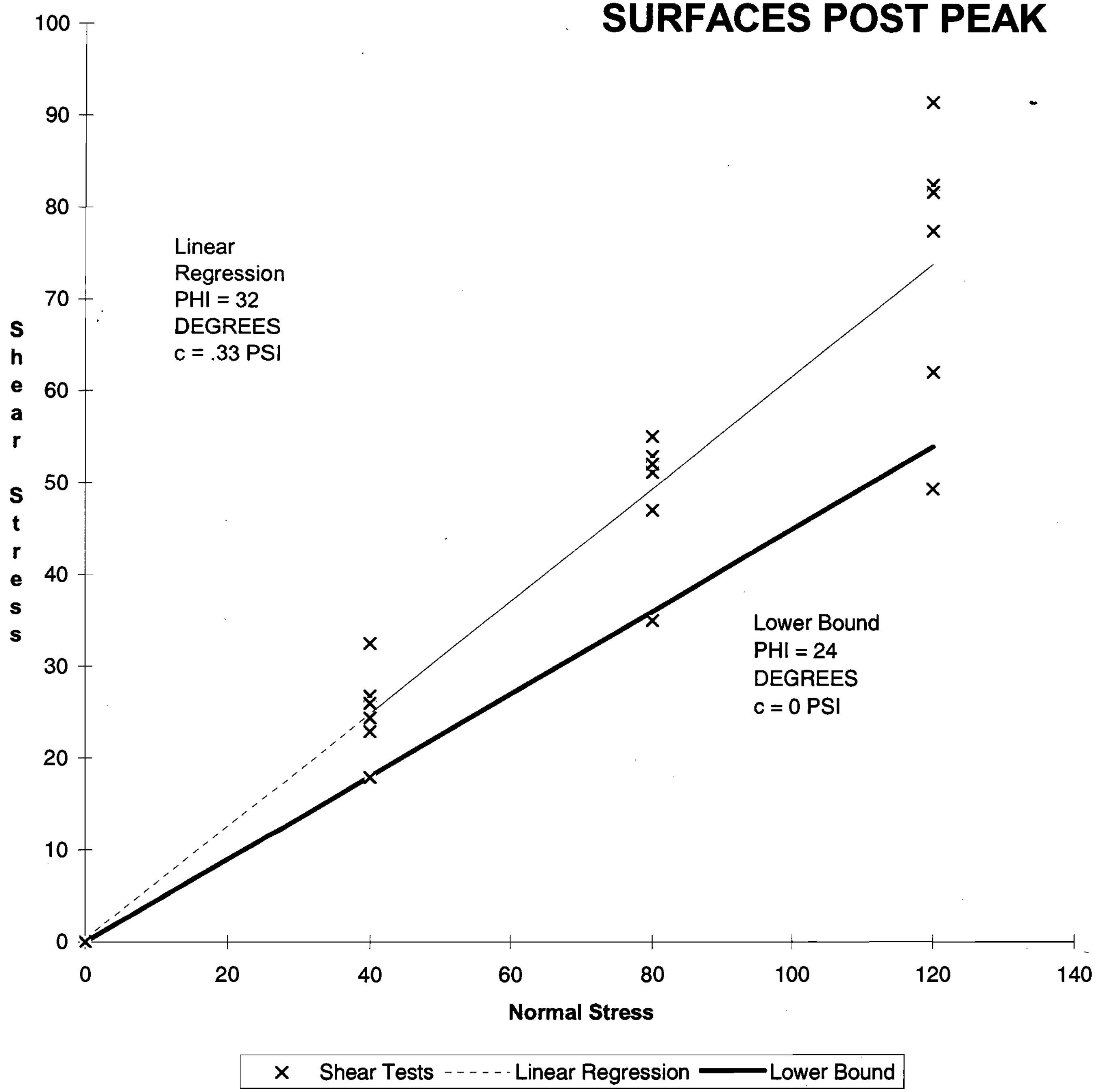
DOVER DAM SANDY SILTSTONE-GROUT-ON-ROCK SAWN SURFACES PEAK



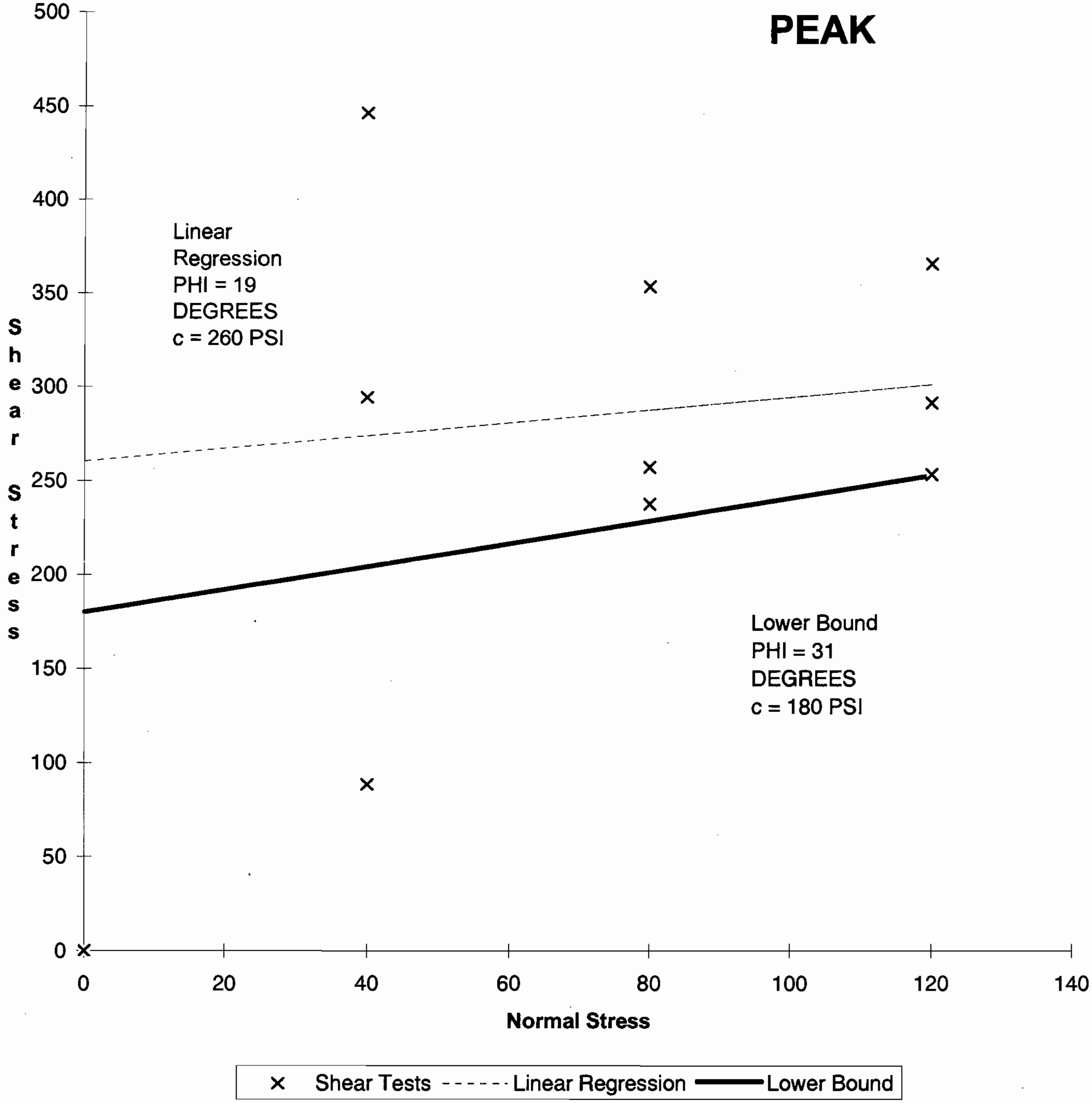
DOVERSANDYSILTSTONEGROUTONROCK.xls

DOVER DAM SANDY SILTSTONE-GROUT-ON-ROCK SAWN SURFACES POST PEAK



DOVERSANDYSILTSTONEGROUTONROCKPOSTPEAK.xls

DOVER DAM SILTSTONE-GROUT-ON-ROCK SAWN SURFACES PEAK



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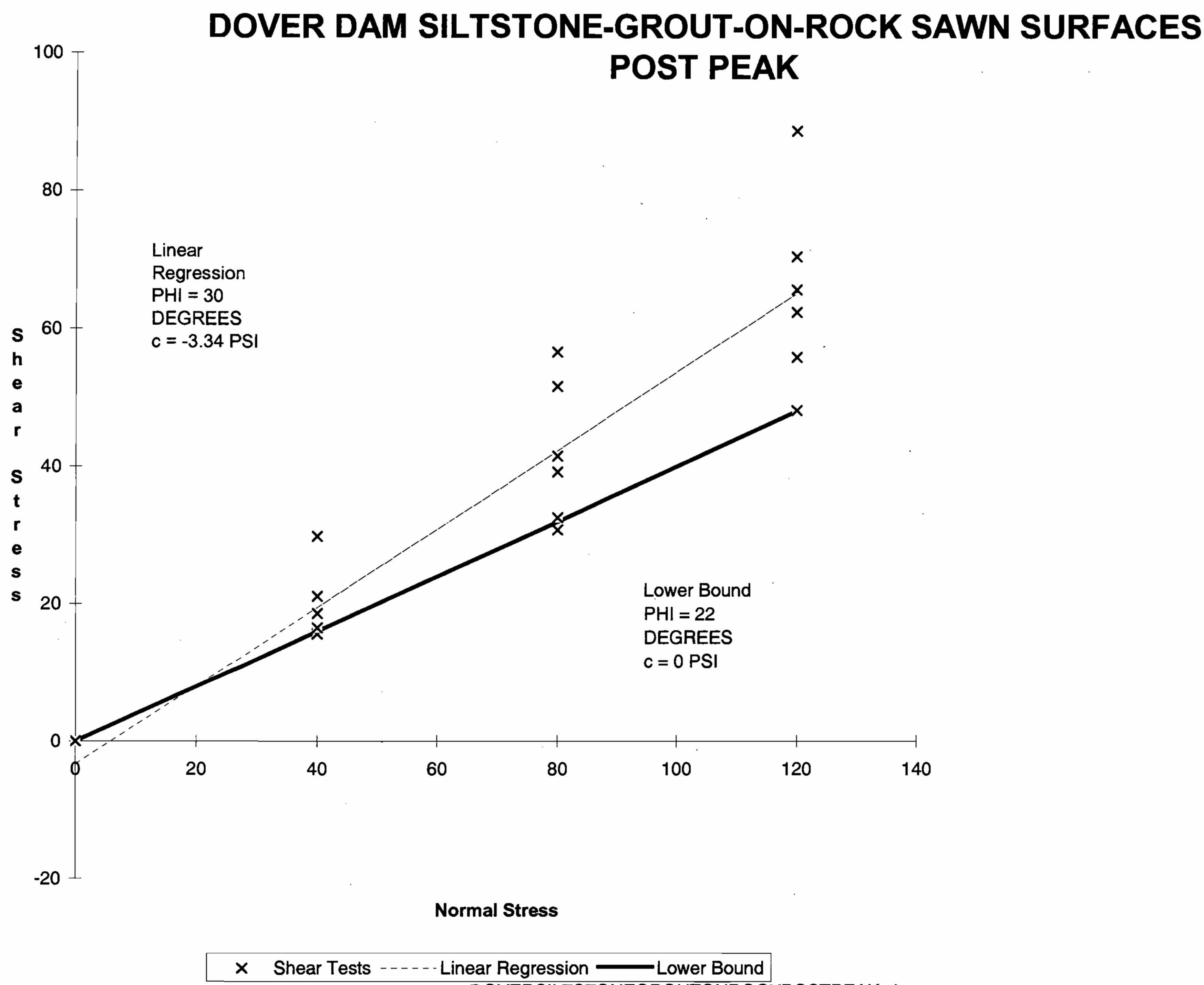
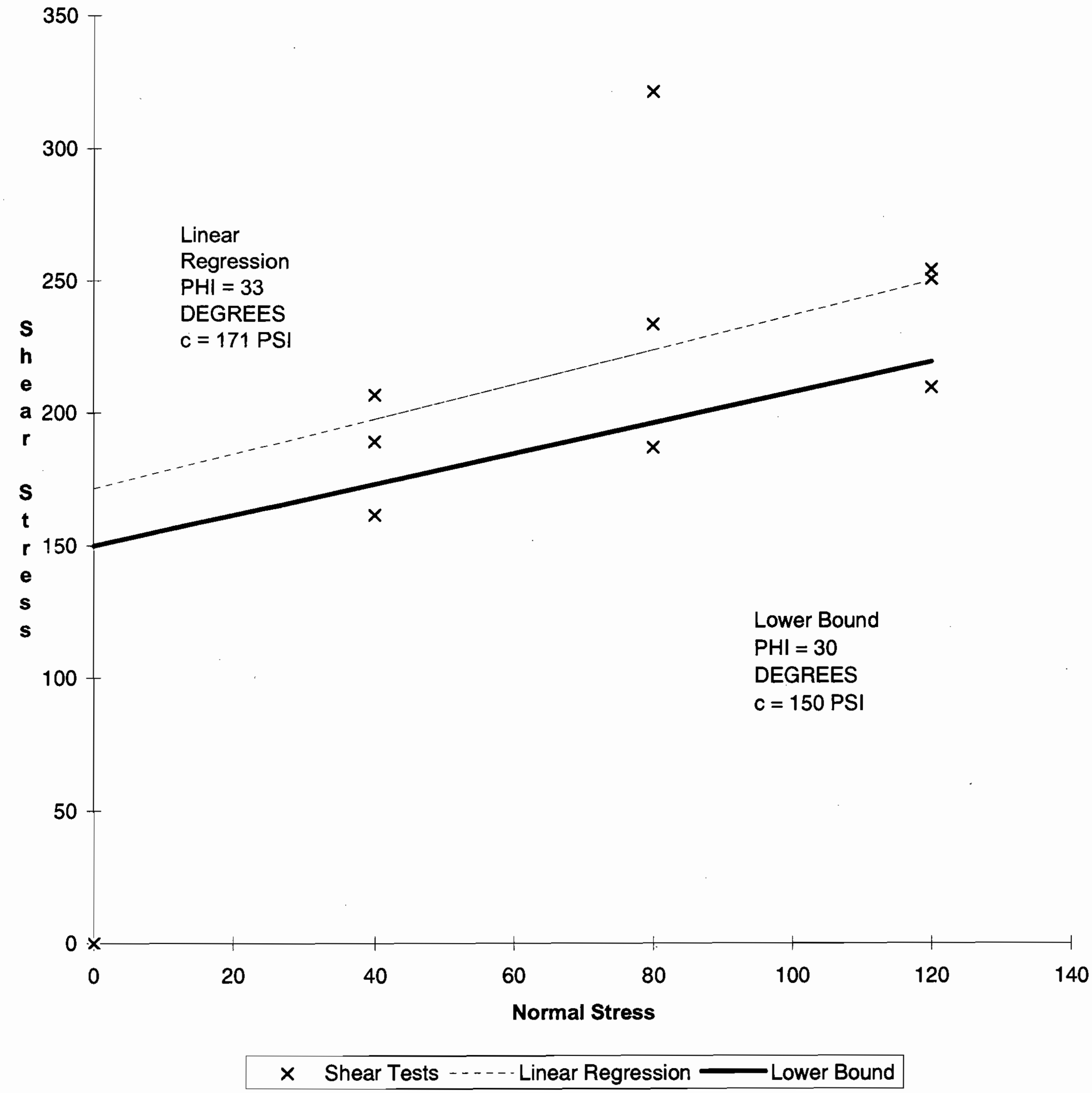
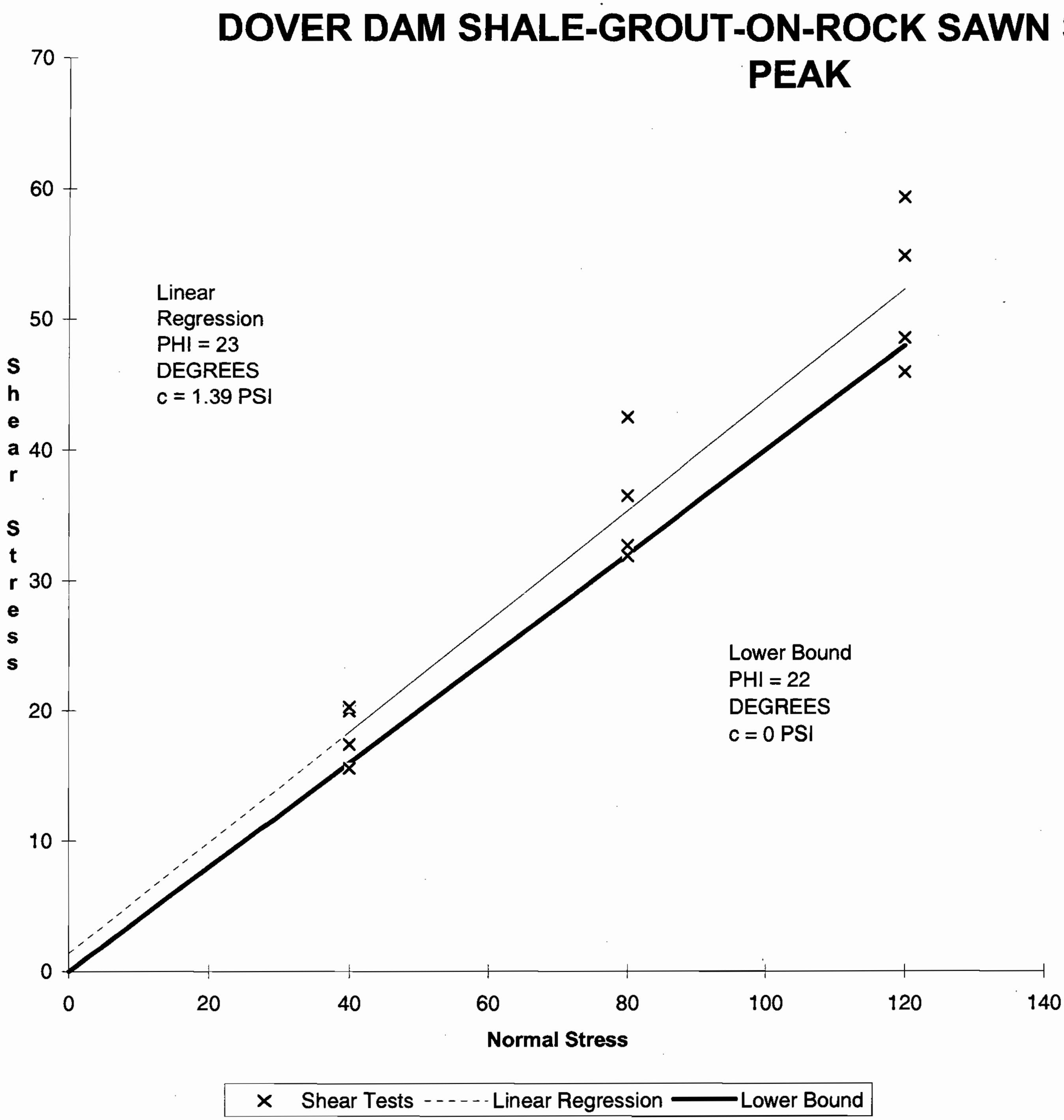


DOVERSILTSTONEGROUTONROCKPOSTPEAK.xls

DOVER DAM SHALE-GROUT-ON-ROCK SAWN SURFACES PEAK



DOVERSHALEGROUTONROCK.xls



DOVERSHALEGROUTONROCKPOSTPEAK.xls

Summary of Rock Testing Results
Direct Shear of Grout-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Limestone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSGR-148	1	C-04-06	53.8	40.0	43.6	24.3
				80.0		38.0
				120.0		53.0
DSGR-149	2	C-04-06	54.2	80.0	359.2	33.6
				40.0		21.4
				120.0		66.9
DSGR-150	3	C-04-05A	53.3	120.0	233.7	56.1
				40.0		19.5
				80.0		37.7
DSGR-151	4	C-04-09	32.1	40.0	183.0	29.3
				80.0		51.1
				120.0		74.3
DSGR-152	5	C-04-09	34.0	80.0	60.8	40.7
				40.0		18.1
				120.0		56.6
DSGR-153	6	C-04-09	33.1	120.0	251.8	59.5
				40.0		16.6
				80.0		37.0
DSGR-154	7	C-04-11	20.0	40.0	26.2	24.5
				80.0		45.2
				120.0		66.1
DSGR-155	8	C-04-13	79.6	80.0	432.7	53.1
				40.0		27.0
				120.0		83.6
DSGR-156	9	C-04-13	83.1	120.0	502.6	64.2
				40.0		19.6
				80.0		42.4

Summary of Rock Testing Results
Direct Shear of Grout-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Upper Sandstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSGR-121	1	C-04-01	20.4	40.0	328.5	24.8
				80.0		49.9
				120.0		72.9
DSGR-122	2	C-04-01	38.5	80.0	297.6	56.3
				40.0		23.7
				120.0		76.7
DSGR-123	3	C-04-01	39.2	120.0	316.1	84.1
				40.0		24.6
				80.0		52.6
DSGR-124	4	C-04-01	45.7	40.0	451.3	31.8
				80.0		60.7
				120.0		76.1
DSGR-125	5	C-04-01	46.7	80.0	448.2	61.2
				40.0		31.0
				120.0		85.7
DSGR-126	6	C-04-14	32.9	120.0	490.3	79.1
				40.0		24.5
				80.0		48.7
DSGR-127	7	C-04-14	39.8	40.0	318.6	26.7
				80.0		52.8
				120.0		80.8
DSGR-128	8	C-04-13	38.7	80.0	461.1	56.8
				40.0		27.4
				120.0		75.3
DSGR-129	9	C-04-13	40.8	120.0	428.3	84.0
				40.0		24.0
				80.0		49.1

Summary of Rock Testing Results
Direct Shear of Grout-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone / Sandy

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSGR-130	1	C-04-06	62.6	40.0	267.8	17.9
				80.0		35.0
				120.0		49.4
DSGR-131	2	C-04-06	63.9	80.0	178.2	47.1
				40.0		24.4
				120.0		62.1
DSGR-132	3	C-04-06	89.4	120.0	437.8	91.5
				40.0		26.8
				80.0		55.1
DSGR-133	4	C-04-06	101.3	40.0	316.8	26.0
				80.0		52.9
				120.0		82.5
DSGR-134	5	C-04-09	53.2	80.0	420.7	51.2
				40.0		22.9
				120.0		77.5
DSGR-135	6	C-04-09	56.9	120.0	266.6	81.7(1)
				40.0		32.5
				80.0		52.1
DSGR-136	7	C-04-09	66.5	40.0	280.3	27.8
				80.0		49.8
				120.0		74.1
DSGR-137	8	C-04-09	66.8	80.0	426.7	48.7
				40.0		24.4
				120.0		73.0
DSGR-138	9	C-04-09	70.7	120.0	456.5	80.7
				40.0		24.1
				80.0		52.9

Note(s): (1). Shear plane extended in Hydro-stone encasement and additional preparation was performed prior to additional shearing.

Summary of Rock Testing Results
Direct Shear of Grout-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Siltstone

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSGR-157	1	C-04-06	79.6	40.0	446.4	21.1
				80.0		56.6
				120.0		88.7
DSGR-158	2	C-04-06	83.0	80.0	353.7	32.6
				40.0		15.7
				120.0		48.1
DSGR-159	3	C-04-06	83.75	120.0	291.9	62.4(1)
				40.0		18.6
				80.0		30.8
DSGR-160	4	C-04-05A	83.8	40.0	88.6	29.9
				80.0		51.6
				120.0		70.4
DSGR-161	5	C-04-10	46.6	80.0	238.0	41.5
				40.0		15.6
				120.0		55.8
DSGR-162	6	C-04-10	47.3	120.0	253.8	65.6
				40.0		16.5
				80.0		39.2
DSGR-163	7	C-04-07	72.3	40.0	294.5	24.5
				80.0		45.5
				120.0		65.4
DSGR-164	8	C-04-07	72.6	80.0	257.3	38.1
				40.0		17.4
				120.0		47.9
DSGR-165	9	C-04-07	75.6	120.0	366.3	67.4
				40.0		16.5
				80.0		33.7

Note(s): (1). Shear plane extended in Hydro-stone encasement and additional preparation was performed prior to additional shearing.

Summary of Rock Testing Results
Direct Shear of Grout-on-Rock Sawn Surfaces

Dover Dam Rock Testing
Dover, Tuscarawas County, Ohio

Shale

FMSM ID No.	USACE Test No.	Boring	Depth (feet)	Normal Stress (psi)	Peak Shear Stress (psi)	Post Peak Shear Stress (psi)
DSGR-139	1	C-04-13	92.4	40.0	206.9	20.0
				80.0		31.9
				120.0		46.0
DSGR-140	2	C-04-13	93.6	80.0	321.6	42.5
				40.0		15.6
				120.0		54.9
DSGR-141	3	C-04-06	42.1	120.0	250.9	59.4
				40.0		17.4
				80.0		32.7
DSGR-142	4	C-04-05A	40.4	40.0	161.7	20.3
				80.0		36.5
				120.0		48.6
DSGR-143	5	C-04-05A	41.1	80.0	187.2	36.5
				40.0		17.3
				120.0		47.9
DSGR-144	6	C-04-05A	41.8	120.0	254.4	56.3
				40.0		18.8
				80.0		33.6
DSGR-145	7	C-04-05A	43.5	40.0	189.2	19.1
				80.0		32.6
				120.0		47.3
DSGR-146	8	C-04-05A	44.4	80.0	233.7	39.8
				40.0		20.5
				120.0		54.9
DSGR-147	9	C-04-05A	44.8	120.0	209.9	52.8
				40.0		17.4
				80.0		29.6

DOVER - LIMESTONE
ALLOWABLE BEARING CAPACITY

INPUT PARAMETERS

c = cohesion:	**150**	psi	Required input for equations 6-1, 6-4, 6-5, 6-6	21600.0 psf
ϕ = phi angle:	**65**	degree	Required input for all equations	
D=depth of foundation below ground surface:	**3**	ft	Required input for equations 6-1, 6-3	
γ = effective unit weight of the rock mass:	**98**	pcf	Required input for equations 6-1, 6-3, 6-4	
B= width of the foundation:	**35**	ft	Required input for equations 6-1, 6-3, 6-4, 6-6, Goodman	
J = correction factor (see figure 6-2 of EM 1110-1-2908):	**1.0**		Required input for equation 6-6	
L = length of foundation:	**65.0**	ft	Required input for equation 6-6 (strip foundation shape) and L/B ratio	
S = Joint spacing:	**20.0**	ft	Required input for equations 6-6 and Goodman	
(q_u) = unconfined compressive strength:	**19353**	psi	Required input for equations 6-7 (cohesion equation) and Goodman	
(RMR) Rock Mass Rating:	**37**		Required input for equations 6-7 (cohesion equation)	
FS = factor of safety (min. 3, see eq. 6-11 EM 1110-1-2908):	**3**		Required input for all equations, separate Goodman FS input.	

COHESION EQUATION (equation 6-7)

s = 0.001

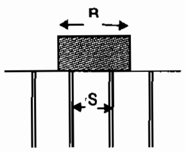
(c) cohesion = 2 psi

MISCELLANEOUS STEPS

$N_\phi=\tan^2(45+\phi/2)$	20.33				
$N_\gamma=N_\phi^{1/2}(N_\phi^2-1)$	1858.44	1765.52	1672.59	1579.67	1300.91
$N_q=N_\phi^2$	413.20				
$N_c=2N_\phi^{1/2}(N_\phi+1)$	192.31	201.93	215.39	240.39	230.77
$N_{cr} = 2N_\phi^2/1+N_\phi (\cot\phi)(S/B)(1-1/N_\phi) - N_\phi(\cot\phi) + 2N_\phi^{1/2}$	9.4				

COMPRESSIVE FAILURE (equation 6-5, EM 1110-1-2908)

MODE: open, near vertical joint set(s) S<B: compressive failure of individual rock columns.



$q_{ult} = 2\,c\,\tan(45 + \phi/2)$

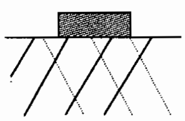
q_{ult} = ultimate bearing capacity: 1353 psi

q_a = allowable bearing capacity: 451 psi

GENERAL SHEAR FAILURE WITHOUT COHESION (equation 6-3, EM 1110-1-2908)

MODE 1: moderately dipping joint set(s) S<B or S>B: general shear failure with potential for failure along joints.

MODE 2: two or more closely space joint sets. S<<B: general shear failure with irregular failure surface through rock mass.



$q_{ult}=0.5\gamma BN_\gamma+\gamma DN_q$

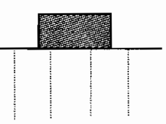
L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	3308701 psf	3149340 psf	2989979 psf	2830618 psf	2352535 psf
	22977 psi	21870 psi	20764 psi	19657 psi	16337 psi
q_a = allowable bearing capacity	**7659 psi**	**7290 psi**	**6921 psi**	**6552 psi**	**5446 psi**

GENERAL SHEAR FAILURE WITH COHESION (equation 6-1, EM 1110-1-2908)

MODE 1: ductile, intact rock or with few joints S>>B : general shear failure along well defined failure surfaces.

MODE 2. Closed, near vertical joint set(s) S<B: general shear failure along well defined failure surfaces.



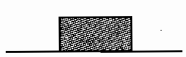
$q_{ult}=cN_c+0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	7462639 psf	7510975 psf	7642389 psf	8023040 psf	7337261 psf
	51824 psi	52160 psi	53072 psi	55716 psi	50953 psi
q_a = allowable bearing capacity	**17275 psi**	**17387 psi**	**17691 psi**	**18572 psi**	**16984 psi**

LOCAL SHEAR FAILURE (equation 6-4, EM 1110-1-2908)

MODE: brittle intact rock or with few joints S>>B: local shear failure caused by localized brittle fracture



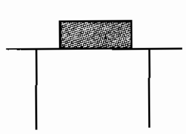
$q_{ult}=cN_c+0.5\gamma BN_\gamma$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	7341158 psf	7389494 psf	7520909 psf	7901560 psf	7215780 psf
	50980 psi	51316 psi	52229 psi	54872 psi	50110 psi
q_a = allowable bearing capacity	**16993 psi**	**17105 psi**	**17410 psi**	**18291 psi**	**16703 psi**

SPLITTING FAILURE (equation 6-6, EM 1110-1-2908)

MODE: open or closed, widely spaced and vertical joints S>B: Failure initiated by splitting leading to general shear failure.



	strip L/B=<32	square	circular
q_{ult} = ultimate bearing capacity	554 psi	1193 psi	1403 psi
q_a = allowable bearing capacity	**185 psi**	**398 psi**	**468 psi**

GOODMAN EQUATION (Introduction to Rock Mechanics,1980, P311, EQ 9.8)

F.S. = factor of safety: **5** (Additional input value)

Nsubphi =	20.262024
NPhi-1 =	19.262024
S/B =	0.5714286
Intermediate	10.902537
Intermediate	0.566012
Capacity =	10954

q_a = allowable bearing capacity: 2191 psi

DOVER - UPPER SANDSTONE
ALLOWABLE BEARING CAPACITY

INPUT PARAMETERS

c = cohesion:	**88**	psi	Required input for equations 6-1, 6-4, 8-5, 6-6	12672.0 psf
ϕ = phi angle:	**64**	degree	Required input for all equations	
D=depth of foundation below ground surface:	**3**	ft	Required input for equations 6-1, 6-3	
γ = effective unit weight of the rock mass:	**98**	pcf	Required input for equations 6-1, 6-3, 6-4	
B= width of the foundation:	**35**	ft	Required input for equations 6-1, 6-3, 8-4, 6-6, Goodman	
J = correction factor (see figure 6-2 of EM 1110-1-2908):	**1.0**		Required input for equation 6-6	
L = length of foundation:	**65.0**	ft	Required input for equation 6-6 (strip foundation shape) and L/B ratio	
S = Joint spacing:	**20.0**	ft	Required input for equations 6-6 and Goodman	
(q_u) = unconfined compressive strength:	**4614**	psi	Required input for equations 8-7 (cohesion equation) and Goodman	
(RMR) Rock Mass Rating:	**66**		Required input for equations 6-7 (cohesion equation)	
FS = factor of safety (min. 3, see eq. 6-11 EM 1110-1-2908):	**3**		Required input for all equations, separate Goodman FS input.	

COHESION EQUATION (equation 6-7)

s = 0.023

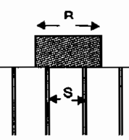
(c) cohesion = 12 psi

MISCELLANEOUS STEPS

$N_\phi=\tan^2(45+\phi/2)$	18.74				
$N_\gamma=N_\phi^{1/2}(N_\phi^2-1)$	1516.92	1441.07	1365.22	1289.38	1061.84
$N_q=N_\phi^2$	351.37				
$N_c=2N_\phi^{1/2}(N_\phi+1)$	170.97	179.52	191.49	213.71	205.16
$N_{cr}=2N_\phi^2/1+N_\phi\ (\cot\phi)\ (S/B)\ (1-1/N_\phi)-N_\phi\ (\cot\phi)+2N_\phi^{1/2}$	8.9				

COMPRESSIVE FAILURE (equation 6-5, EM 1110-1-2908)

MODE: open, near vertical joint set(s) S<B: compressive failure of individual rock columns.



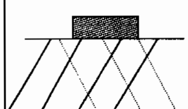
$q_{ult} = 2\ c \tan(45+\phi/2)$

q_{ult} = ultimate bearing capacity: 762 psi

q_a = allowable bearing capacity: 254 psi

GENERAL SHEAR FAILURE WITHOUT COHESION (equation 6-3, EM 1110-1-2908)

MODE 1: moderately dipping joint set(s) S<B or S>B: general shear failure with potential for failure along joints.
MODE 2: two or more closely space joint sets. S<<B: general shear failure with irregular failure surface through rock mass.



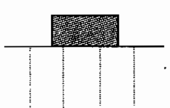
$q_{ult}=0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	2704811 psf	2574735 psf	2444660 psf	2314584 psf	1924358 psf
	18783 psi	17880 psi	16977 psi	16074 psi	13364 psi
q_a = allowable bearing capacity	6261 psi	5960 psi	5659 psi	5358 psi	4455 psi

GENERAL SHEAR FAILURE WITH COHESION (equation 6-1, EM 1110-1-2908)

MODE 1: ductile, intact rock or with few joints S>>B : general shear failure along well defined failure surfaces.
MODE 2. Closed, near vertical joint set(s) S<B: general shear failure along well defined failure surfaces.



$q_{ult}=cN_c+0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	4871350 psf	4849602 psf	4871184 psf	5022759 psf	4524205 psf
	33829 psi	33678 psi	33828 psi	34880 psi	31418 psi
q_a = allowable bearing capacity	11276 psi	11226 psi	11276 psi	11627 psi	10473 psi

LOCAL SHEAR FAILURE (equation 6-4, EM 1110-1-2908)

MODE: brittle intact rock or with few joints S>>B: local shear failure caused by localized brittle fracture

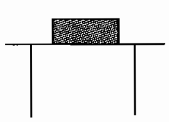
$q_{ult}=cN_c+0.5\gamma BN_\gamma$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	4768049 psf	4746300 psf	4767882 psf	4919457 psf	4420904 psf
	33111 psi	32960 psi	33110 psi	34163 psi	30701 psi
q_a = allowable bearing capacity	11037 psi	10987 psi	11037 psi	11388 psi	10234 psi

SPLITTING FAILURE (equation 6-6, EM 1110-1-2908)

MODE: open or closed, widely spaced and vertical joints S>B: Failure initiated by splitting leading to general shear failure.



	strip L/B=<32	square	circular
q_{ult} = ultimate bearing capacity	309 psi	666 psi	784 psi
q_a = allowable bearing capacity	103 psi	222 psi	261 psi

GOODMAN EQUATION (Introduction to Rock Mechanics,1980, P311, EQ 9.8)

F.S. = factor of safety: 5 (Additional input value)

Nsubphi =	18.886695
NPhi-1 =	17.686695
S/B =	0.5714286
Intermediate	10.002728
Intermediate	0.565551
Capacity =	2609

q_a = allowable bearing capacity: 522 psi

DOVER - SILTSTONE / SANDY
ALLOWABLE BEARING CAPACITY

INPUT PARAMETERS

c = cohesion:	**20** psi	Required input for equations 6-1, 6-4, 6-5, 6-6	2880.0 psf
ϕ = phi angle:	**46** degree	Required input for all equations	
D=depth of foundation below ground surface:	**3** ft	Required input for equations 6-1, 6-3	
γ = effective unit weight of the rock mass:	**98** pcf	Required input for equations 6-1, 6-3, 6-4	
B= width of the foundation:	**35** ft	Required input for equations 6-1, 6-3, 6-4, 6-6, Goodman	
J = correction factor (see figure 6-2 of EM 1110-1-2908):	**1.0**	Required input for equation 6-6	
L = length of foundation:	**65.0** ft	Required input for equation 6-6 (strip foundation shape) and L/B ratio	
S = Joint spacing:	**20.0** ft	Required input for equations 6-6 and Goodman	
(q_u) = unconfined compressive strength:	**7494** psi	Required input for equations 6-7 (cohesion equation) and Goodman	
(RMR) Rock Mass Rating:	**51**	Required input for equations 6-7 (cohesion equation)	
FS = factor of safety (min. 3, see eq. 6-11 EM 1110-1-2908):	**3**	Required input for all equations, separate Goodman FS input.	

COHESION EQUATION (equation 6-7)

s = 0.004

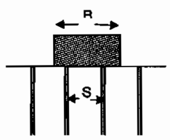
(c) cohesion = 7 psi

MISCELLANEOUS STEPS

$N_\phi = \tan^2(45+\phi/2)$	6.12				
$N_\gamma = N_\phi^{1/2}(N_\phi^2-1)$	90.30	85.78	81.27	76.75	63.21
$N_q = N_\phi^2$	37.49				
$N_c = 2N_\phi^{1/2}(N_\phi+1)$	35.25	37.01	39.48	44.06	42.30
$N_{cr} = 2N_\phi^2/1+N_\phi(\cot\phi)(S/B)(1-1/N_\phi) - N_\phi(\cot\phi) + 2N_\phi^{1/2}$	3.9				

COMPRESSIVE FAILURE (equation 6-5, EM 1110-1-2908)

MODE: open, near vertical joint set(s) S<B: compressive failure of individual rock columns.



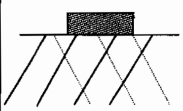
$q_{ult} = 2\,c\tan(45+\phi/2)$

q_{ult} = ultimate bearing capacity: 99 psi

q_a = allowable bearing capacity: 33 psi

GENERAL SHEAR FAILURE WITHOUT COHESION (equation 6-3, EM 1110-1-2908)

MODE 1: moderately dipping joint set(s) S<B or S>B: general shear failure with potential for failure along joints.
MODE 2: two or more closely space joint sets. S<<B: general shear failure with irregular failure surface through rock mass.



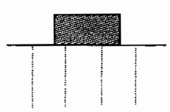
$q_{ult} = 0.5\gamma BN_\gamma + \gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	165878 psf	158136 psf	150393 psf	142650 psf	119422 psf
	1152 psi	1098 psi	1044 psi	991 psi	829 psi
q_a = allowable bearing capacity	**384** psi	**366** psi	**348** psi	**330** psi	**276** psi

GENERAL SHEAR FAILURE WITH COHESION (equation 6-1, EM 1110-1-2908)

MODE 1: ductile, intact rock or with few joints S>>B : general shear failure along well defined failure surfaces.
MODE 2. Closed, near vertical joint set(s) S<B: general shear failure along well defined failure surfaces.



$q_{ult} = cN_c + 0.5\gamma BN_\gamma + \gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	267402 psf	264735 psf	264099 psf	269554 psf	241249 psf
	1857 psi	1838 psi	1834 psi	1872 psi	1675 psi
q_a = allowable bearing capacity	**619** psi	**613** psi	**611** psi	**624** psi	**558** psi

LOCAL SHEAR FAILURE (equation 6-4, EM 1110-1-2908)

MODE: brittle intact rock or with few joints S>>B: local shear failure caused by localized brittle fracture

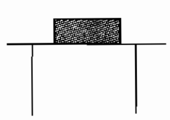
$q_{ult} = cN_c + 0.5\gamma BN_\gamma$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	256379 psf	253713 psf	253076 psf	258532 psf	230227 psf
	1780 psi	1762 psi	1757 psi	1795 psi	1599 psi
q_a = allowable bearing capacity	**593** psi	**587** psi	**566** psi	**598** psi	**533** psi

SPLITTING FAILURE (equation 6-6, EM 1110-1-2908)

MODE: open or closed, widely spaced and vertical joints S>B: Failure initiated by splitting leading to general shear failure.



	strip L/B=<32	square	circular
q_{ult} = ultimate bearing capacity	31 psi	66 psi	78 psi
q_a = allowable bearing capacity	**10** psi	**22** psi	**26** psi

GOODMAN EQUATION (Introduction to Rock Mechanics,1980, P311, EQ 9.8)

F.S. = factor of safety: **5** (Additional input value)

Nsubphi =	6.1109919
NPhi-1 =	5.1109919
S/B =	0.5714286
Intermediate	2.8268752
Intermediate	0.5530972
Capacity =	4145

q_a = allowable bearing capacity: 829 psi

DOVER - SILTSTONE
ALLOWABLE BEARING CAPACITY

INPUT PARAMETERS

c = cohesion:	15 psi	Required input for equations 6-1, 6-4, 6-5, 6-6	2160.0 psf
ϕ = phi angle:	31 degree	Required input for all equations	
D=depth of foundation below ground surface:	3 ft	Required input for equations 6-1, 6-3	
γ = effective unit weight of the rock mass:	98 pcf	Required input for equations 6-1, 6-3, 6-4	
B= width of the foundation:	35 ft	Required input for equations 6-1, 6-3, 6-4, 6-6, Goodman	
J = correction factor (see figure 6-2 of EM 1110-1-2908):	1.0	Required input for equation 6-6	
L = length of foundation:	65.0 ft	Required input for equation 6-6 (strip foundation shape) and L/B ratio	
S = Joint spacing:	20.0 ft	Required input for equations 6-6 and Goodman	
(q_u) = unconfined compressive strength:	8170 psi	Required input for equations 6-7 (cohesion equation) and Goodman	
(RMR) Rock Mass Rating:	52	Required input for equations 6-7 (cohesion equation)	
FS = factor of safety (min. 3, see eq. 6-11 EM 1110-1-2908):	3	Required input for all equations, separate Goodman FS input.	

COHESION EQUATION (equation 6-7)

s = 0.005

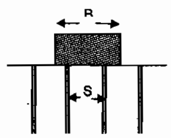
(c) cohesion = 11 psi

MISCELLANEOUS STEPS

$N_\phi=\tan^2(45+\phi/2)$	3.12				
$N_\gamma=N_\phi^{1/2}(N_\phi^2-1)$	15.47	14.69	13.92	13.15	10.83
$N_q=N_\phi^2$	9.75				
$N_c=2N_\phi^{1/2}(N_\phi+1)$	14.57	15.30	16.32	18.21	17.49
$N_{cr}=2N_\phi^2/1+N_\phi(\cot\phi)(S/B)(1-1/N_\phi)-N_\phi(\cot\phi)+2N_\phi^{1/2}$	1.4				

COMPRESSIVE FAILURE (equation 6-5, EM 1110-1-2908)

MODE: open, near vertical joint set(s) S<B: compressive failure of individual rock columns.



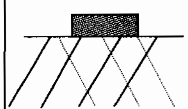
$q_{ult}=2c\tan(45+\phi/2)$

q_{ult} = ultimate bearing capacity: 31 psi

q_a = allowable bearing capacity: 10 psi

GENERAL SHEAR FAILURE WITHOUT COHESION (equation 6-3, EM 1110-1-2908)

MODE 1: moderately dipping joint set(s) S<B or S>B: general shear failure with potential for failure along joints.
MODE 2: two or more closely space joint sets. S<<B: general shear failure with irregular failure surface through rock mass.



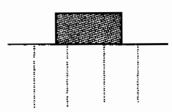
$q_{ult}=0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	29394 psf	28067 psf	26741 psf	25415 psf	21436 psf
	204 psi	195 psi	186 psi	176 psi	149 psi
q_a = allowable bearing capacity	68 psi	65 psi	62 psi	59 psi	50 psi

GENERAL SHEAR FAILURE WITH COHESION (equation 6-1, EM 1110-1-2908)

MODE 1: ductile, intact rock or with few joints S>>B : general shear failure along well defined failure surfaces.
MODE 2. Closed, near vertical joint set(s) S<B: general shear failure along well defined failure surfaces.



$q_{ult}=cN_c+0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	60869 psf	61116 psf	61993 psf	64758 psf	59206 psf
	423 psi	424 psi	431 psi	450 psi	411 psi
q_a = allowable bearing capacity	141 psi	141 psi	144 psi	150 psi	137 psi

LOCAL SHEAR FAILURE (equation 6-4, EM 1110-1-2908)

MODE: brittle intact rock or with few joints S>>B: local shear failure caused by localized brittle fracture

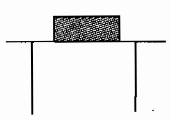
$q_{ult}=cN_c+0.5\gamma BN_\gamma$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	58001 psf	58249 psf	59126 psf	61891 psf	56338 psf
	403 psi	405 psi	411 psi	430 psi	391 psi
q_a = allowable bearing capacity	134 psi	135 psi	137 psi	143 psi	130 psi

SPLITTING FAILURE (equation 6-6, EM 1110-1-2908)

MODE: open or closed, widely spaced and vertical joints S>B: Failure initiated by splitting leading to general shear failure.



	strip L/B=<32	square	circular
q_{ult} = ultimate bearing capacity	8 psi	18 psi	21 psi
q_a = allowable bearing capacity	3 psi	6 psi	7 psi

GOODMAN EQUATION (Introduction to Rock Mechanics,1980, P311, EQ 9.8)

F.S. = factor of safety: 5 (Additional input value)

Nsubphi =	3.1179475
NPhi-1 =	2.1179475
S/B =	0.5714286
Intermediate	1.1319589
Intermediate	0.5344603
Capacity =	4367

q_a = allowable bearing capacity: 873 psi

DOVER - SHALE
ALLOWABLE BEARING CAPACITY

INPUT PARAMETERS

c = cohesion:	5 psi	Required input for equations 6-1, 6-4, 6-5, 6-6	720.0 psf
ϕ = phi angle:	29 degree	Required input for all equations	
D=depth of foundation below ground surface:	3 ft	Required input for equations 6-1, 6-3	
γ = effective unit weight of the rock mass:	98 pcf	Required input for equations 6-1, 6-3, 6-4	
B= width of the foundation:	35 ft	Required input for equations 6-1, 6-3, 6-4, 6-6, Goodman	
J = correction factor (see figure 6-2 of EM 1110-1-2908):	1.0	Required input for equation 6-6	
L = length of foundation:	65.0 ft	Required input for equation 6-6 (strip foundation shape) and L/B ratio	
S = Joint spacing:	20.0 ft	Required input for equations 6-6 and Goodman	
(q_u) = unconfined compressive strength:	2822 psi	Required input for equations 6-7 (cohesion equation) and Goodman	
(RMR) Rock Mass Rating:	25	Required input for equations 6-7 (cohesion equation)	
FS = factor of safety (min. 3, see eq. 6-11 EM 1110-1-2908):	3	Required input for all equations, separete Goodman FS input.	

COHESION EQUATION (equation 6-7)

s = 0.000

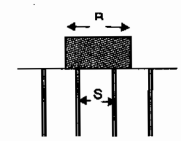
(c) cohesion = 0 psi

MISCELLANEOUS STEPS

$N_\phi=\tan^2(45+\phi/2)$	2.88				
$N_\gamma=N_\phi^{1/2}(N_\phi^2-1)$	12.39	11.77	11.15	10.53	8.67
$N_q=N_\phi^2$	8.30				
$N_c=2N_\phi^{1/2}(N_\phi+1)$	13.18	13.83	14.76	16.47	15.81
$N_{cr} = 2N_\phi^2/1+N_\phi$ (cot ϕ) (S/B) (1-1/N_ϕ) - N_ϕ (cot ϕ) + $2N_\phi^{1/2}$	1.1				

COMPRESSIVE FAILURE (equation 6-5, EM 1110-1-2908)

MODE: open, near vertical joint set(s) S<B: compressive failure of individual rock columns.



$q_{ult} = 2\ c \tan(45 + \phi/2)$

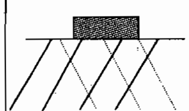
q_{ult} = ultimate bearing capacity: 17 psi

q_a = allowable bearing capacity: 6 psi

GENERAL SHEAR FAILURE WITHOUT COHESION (equation 6-3, EM 1110-1-2908)

MODE 1: moderately dipping joint set(s) S<B or S>B: general shear failure with potential for failure along joints.

MODE 2: two or more closely space joint sets. S<<B: general shear failure with irregular failure surface through rock mass.



$q_{ult}=0.5\gamma BN_\gamma+\gamma DN_q$

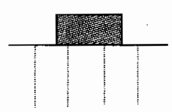
L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	23692 psf	22629 psf	21567 psf	20504 psf	17316 psf
	165 psi	157 psi	150 psi	142 psi	120 psi
q_a = allowable bearing capacity	55 psi	52 psi	50 psi	47 psi	40 psi

GENERAL SHEAR FAILURE WITH COHESION (equation 6-1, EM 1110-1-2908)

MODE 1: ductile, intact rock or with few joints S>>B : general shear failure along well defined failure surfaces.

MODE 2. Closed, near vertical joint set(s) S<B: general shear failure along well defined failure surfaces.



$q_{ult}=cN_c+0.5\gamma BN_\gamma+\gamma DN_q$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	33178 psf	32590 psf	32191 psf	32362 psf	28700 psf
	230 psi	226 psi	224 psi	225 psi	199 psi
q_a = allowable bearing capacity	77 psi	75 psi	75 psi	75 psi	66 psi

LOCAL SHEAR FAILURE (equation 6-4, EM 1110-1-2908)

MODE: brittle intact rock or with few joints S>>B: local shear failure caused by localized brittle fracture

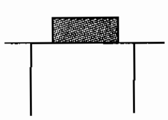
$q_{ult}=cN_c+0.5\gamma BN_\gamma$

L/B ratio: 1.8571

	strip L/B=>10	strip L/B=5	strip L/B=2	square	circular
q_{ult} = ultimate bearing capacity	30738 psf	30149 psf	29751 psf	29921 psf	26259 psf
	213 psi	209 psi	207 psi	208 psi	182 psi
q_a = allowable bearing capacity	71 psi	70 psi	69 psi	69 psi	61 psi

SPLITTING FAILURE (equation 6-6, EM 1110-1-2908)

MODE: open or closed, widely spaced and vertical joints S>B: Failure initiated by splitting leading to general shear failure.



	strip L/B=<32	square	circular
q_{ult} = ultimate bearing capacity	2 psi	5 psi	5 psi
q_a = allowable bearing capacity	1 psi	2 psi	2 psi

GOODMAN EQUATION (Introduction to Rock Mechanics,1980, P311, EQ 9.8)

F.S. = factor of safety: 5 (Additional input value)

Nsubphi =	2.8765727
NPhi-1 =	1.8765727
S/B =	0.5714286
Intermediate	0.9967609
Intermediate	0.5311603
Capacity =	1499

q_a = allowable bearing capacity: 300 psi

DOVER DSA

Lithology: LIMESTONE

Boring	Tested depth	Compressive Strength (PSI)	E_{t50} Elastic Modulus (x10^6)
C-04-03	81.7 - 82.5	20,810	32.95
C-04-03	83.0 - 83.7	18,910	19.48
C-04-06	50.6 - 51.3	19,790	45.22*
C-04-05A	52.1 - 52.8	20,190	31.31
C-04-13	49.0 - 49.7	20,200	15.22

Average Compressive Strength=	19,980	Average Elastic Modulus=	24.74
STDEVP=	626.48	STDEVP=	7.56
Average minus one STDEVP =	**19,353.52**		

*Note test results accompanied by * were not used in the statistical equations

DOVER DSA

Lithology: Upper Sandstone

Boring	Tested depth	Compressive Strength (PSI)	E_{t50} Elastic Modulus (x10^6)
C-04-01	12.3 - 13.1	5,210	1.49
C-04-02	14.9 - 15.7	6,800	1.53
C-04-03	43.4 - 44.1	5,550	2.22
C-04-14	23.3 - 24.0	8,710	3.77
C-04-14	41.4 - 42.2	4,360	1.23

Average Compressive Strength=	6,126	Average Elastic Modulus=	2.05
STDEVP=	1,511.35	STDEVP=	0.92
Average minus one STDEVP =	**4,614.65**		

*Note test results accompanied by * were not used in the statistical equations

DOVER DSA

Lithology: Lower Sandstone

Boring	**Tested depth**	**Compressive Strength (PSI)**	**E_{t50} Elastic Modulus (x10^6)**
C-04-06	61.3 - 62.0	8,270	2.81
C-04-06	65.6 - 66.4	14,900	3.80
C-04-06	97.0 - 97.8	3070*	2.06*
C-04-09	54.3 - 55.0	8,530	2.50
C-04-09	60.3 - 61.1	9,170	2.75

Average Compressive Strength=	10,218	Average Elastic Modulus=	2.97
STDEVP=	2,723.21	STDEVP=	0.50
Average minus one STDEVP =	**7,494.29**		

*Note test results accompanied by * were not used in the statistical equations

DOVER DSA

Lithology: Siltstone

Boring	**Tested depth**	**Compressive Strength (PSI)**	**E_{t50} Elastic Modulus (x10^6)**
C-04-04	100.3 - 101.0	8,240	3.03
C-04-05A	79.0 - 79.7	8,270	3.03
C-04-10	44.3 - 45.0	13,040	2.60
C-04-09	48.6 - 49.3	10,170	4.26*
C-04-10	41.4 - 42.1	9,890	2.33

Average Compressive Strength=	9,922	Average Elastic Modulus=	2.75
STDEVP=	1,751.72	STDEVP=	0.30
Average minus one STDEVP =	**8,170.28**		

*Note test results accompanied by * were not used in the statistical equations

DOVER DSA

Lithology: Shale

Boring	**Tested depth**	**Compressive Strength (PSI)**	**E_{t50} Elastic Modulus (x10^6)**
C-04-01	60.2 - 61.5*	410*	0.03*
C-04-01	67.1 - 67.8	2,750	1.67
C-04-01	72.0 - 72.8	2,940	1.81
C-04-13	87.2 - 87.9	4,320	1.76
C-04-13	90.0 - 90.8*	3,880	7.23*

Average Compressive Strength=	3,473	Average Elastic Modulus=	1.75
STDEVP=	649.98	STDEVP=	0.06
Average minus one STDEVP =	**2,822.52**		

*Note test results accompanied by * were not used in the statistical equations

CLASSIFICATION PARAMETERS AND THEIR RATINGS

	PARAMETER		RANGES OF VALUES						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4-10 MPa	2-4 MPa	1-2 MPa	For this low range- Uniaxial compressive test is preferred		
		Uniaxial compressive strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5-25 MPa	1-5 MPa	<1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%		
	Rating		20	17	13	6	3		
3	Spacing Discontinuities		>2m	0.6-2m	200-600mm	60-200mm	<60mm		
	Rating		20	15	10	8	5		
4	Condition of Discontinuities		Very rough surfaces. Not continuous No separation Unweathered wall rock	Slightly rough surfaces. Separation <1mm. Slightly weathered walls	Slightly rough surfaces. Separation <1mm. Highly weathered walls	Slickensided surfaces OR Gouge <5mm thick OR Separation 1-5mm. Continuous.	Soft gouge >5mm thick OR Separation >5mm. Continuous.		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10m tunnel length	None	<10 L/mm	10-25 L/mm	25-125 L/mm	>125 L/mm		
		Ratio $\frac{\text{joint water pressure}}{\text{major principal stress}}$	0	0.0-0.1	0.1-0.2	0.2-0.5	>0.5		
		General Conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

Lithology	PARAMETER 1	2	3	4	5	Joint Orientation Adjustment	Rating Total
Limestone	12	13	10	10	7	-15	37
Upper Sandstone	4	17	15	25	7	-2	66
Siltstone / Sandy	7	17	10	25	7	-15	51
Siltstone	7	20	10	25	7	-15	54
Shale	2	13	8	10	7	-15	25

	ABUTMENT RQD												ABUTMENT RQD								
	Limestone			Upper Sandstone			Sandy Siltstone			Siltstone			Shale			Coal			SS interbedded w/ SH		
Boring	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT
C-04-1	70	1.1	77	93	2.5	232.5							18	4	72	2.4	54	129.6			0
				100	5.0	500							0	3.7	0						
				92	5.0	460							93	2.8	260.4						
				100	5.0	500							54	2.4	129.6						
				90	5.1	459							54	1.7	91.8						
				100	5.0	500							100	4.9	490						
				100	5.0	500							70	4.0	280						
				80	4.9	392															
				91	5.1	464.1															
				18	0.9	16.2															
C-04-2	67	1.0	67	0	2.6	0	100	1	100	91	1.1	100.1	36	3.3	118.8						
	91	1.1	100.1	36	1.1	39.6	71	3.8	269.8	100	5.7	570									
	100	4.2	420	36	0.8	28.8	100	2.0	200												
	100	1.1	110	0	10.1	0	66	5.0	330												
	98	5.0	490	40	4.3	172	100	2.9	290												
	72	5.0	360	71	1.2	85.2	100	3.1	310												
	100	3.8	380	78	5.0	390	100	7.7	770												
				96	5.0	480															
C-04-3	28	2.8	78.4	86	5.0	430	0	1.2	0	88	2.4	211.2	0	2.6	0	50	1.6	80			
	50	0.9	45	100	8.0	800	0	5.0	0				28	2.2	61.6						
	66	2.3	151.8	67	4.0	268	0	4.8	0				50	2.5	125						
	85	1.6	136	91	3.0	273	47	5.2	244.4				88	5.0	440						
			0	100	2.1	210	88	5.0	440				30	5.0	150						
			0	100	4.4	440	90	5.0	450				66	2.7	178.2						
				100	2.4	240	90	5.0	450				85	1.2	102						
				88	5.0	440	92	5.1	469.2				88	3.0	264						
				92	5.0	460	0	2.4	0												
				94	2.8	263.2															
				100	0.6	60															
				100	5.7	570															
				100	6.4	640															
C-04-4	0	1.4	0	0	0.7	0	100	0.8	80				38	2.4	91.2	20	1.3	26			
	20	1.0	20	0	2.8	0	87	4.6	400.2				0	3.7	0						
	72	4.9	352.8	0	3.5	0			0				20	2.7	54						
	31	0.1	3.1	56	5.0	280			0				76	5.1							
			0	62	5.0	310			0				72	4.9							
			0	36	5.1	183.6			0				78	5.0							
			0	38	2.5	95			0				88	4.7							
			0			0			0				31	4.8							
			0			0			0				87	0.7							
			0			0			0												
						0															
C-04-5a	90	3.1	279			0	93	4.9	455.7	90	4.8	432	0	3.3	0			0			0
	45	0.9	40.5			0	94	5.1	479.4	92	1.0	92	24	5.1	122.4						
			0			0	98	4.9	480.2				38	4.9	186.2						
			0			0	98	5.1	499.8				90	1.9	171						
			0			0	92	4.2	386.4				45	4.3	193.5						
			0			0	88	4.9	431.2												
			0			0	80	5.0	400												
			0			0	78	5.1	397.8												
			0			0	67	1.5	100.5												
			0			0			0												
						0															
C-04-6	82	3.5	287			0	98	5.0	490	90	5	450	86	3.9	335.4			0			0
	86	1.1	94.6			0	96	5.0	480	88	0.4	35.2	0	3.5	0						
			0			0	98	5.0	490			0	46	5.0	230						
			0			0	94	5.0	470				38	5.1	193.8						
			0			0	88	4.6	404.8				82	1.5	123						
			0			0	78	4.9	382.2												
			0			0	50	5.0	250												
						0	84	5.0	420												
						0	75	2.2	165												
						0			0												
						0															
C-04-7	100	2.8	280			0	39	1.8	70.2	76	4.8	364.8	46	2.4	110.4						
	46	2.6	119.6			0	100	5.0	500	90	1.7	153	39	3.2	124.8						
						0	100	5.0	500												
						0	100	4.9	490												
						0	92	5.1	469.2												
						0	76	0.2	15.2												
						0	90	3.3	297												
						0	90	5.0	450												
						0	84	5.0	420												
						0	78	5.0	390												
						0															
						0															

	ABUTMENT RQD												ABUTMENT RQD								
	Limestone			Upper Sandstone			Sandy Siltstone			Siltstone			Shale			Coal			SS interbedded w/ SH		
Boring	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT	RQD	THICK	PRODUCT
	96	4.8	460.8			0	44	0.4	17.6			0	34	2.9	98.6	44	0.2	8.8			
			0			0	96	6	576			0	44	2.0	88						
			0			0	90	2.3	207				44	2.4							
			0			0	90	1.7	153												
C-04-8			0			0	94	5.0	470												
			0			0	88	5.0	440												
						0	96	1.3	124.8												
						0	96	3.7	355.2												
						0	87	5.1	443.7												
						0	86	5.0	430												
							65	4.3	279.5												
	100	2.2	220			0	92	4.2	386.4	98	1.5	147	86	0.6	51.6	49	0.2	9.8			
	86	2.2	189.2			0	98	2.7	264.6	100	1.2	120	49	3.8	186.2						
			0			0	100	3.5	350				49	1.0	49						
C-04-9			0			0	80	5.0	400				92	0.9	82.8						
			0			0	98	5.0	490												
			0			0	94	5.0	470												
			0			0	86	5.0	430												
			0			0	86	5.0	430												
			0			0	87	3.0	261												
						0															
	49	1.3	63.7	100	2.8	280	76	2.1	159.6	98	4.9	480.2	82	1.6	131.2	67	0.1	6.7			
	82	3.3	270.6	90	5.0	450	93	5.1	474.3	100	2.3	230	67	2.3	154.1						
				76	2.8	212.8	78	2.6	202.8				67	2.7	180.9						
C-04-10							78	2.4	187.2												
							84	5.0	420												
							86	5.0	430												
							60	1.0	60												
	22	1.5	33										22	1.0	22	22	0.7	15.4			0
													0	2.5	0						
C-04-11													0	2.5	0						
													19	2.1	39.9						
													0	0.8	0						
													0	5.0	0						
C-04-12													27	1.3	35.1						
													27	3.5	94.5						
	78	1.4	109.2	99	1.1	108.9	100	4.4	440			0	99	0.7	69.3	99	0	0	100	3.3	330
	78	2.0	156	92	5.0	460							78	1.4	109.2	78	0.8	62.4			0
	90	4.8	432	93	5.2	483.6							100	0.8	80	80	0.3	24			0
	96	0.7	67.2	100	5.0	500							100	0.9	90						
				100	5.0	500							100	5.0	500						
				62	4.9	303.8							100	5.0	500						
				52	0.5	26							100	5.1	510						
				52	4.5	234							100	5.0	500						
C-04-13				78	0.2	15.6							90	0.1	9						
													96	4.4	422.4						
													80	0.4	32						
													80	4.2	336						
													100	0.7	70						
	82	0.5	41	72	1.3	93.6	74	0.3	22.2				94	2.0	188	72	1.0		72	0.1	7.2
	72	0.6	43.2	94	2.9	272.6	100	5.0	500				82	4.5	369	68	0.3		100	3.7	370
	92	1.1		100	5.1	510							100	1.0	100	30	0.3				
	86	4.4		100	4.9	490							100	5.1	510						
				98	5.2	509.6							100	5.0	500						
C-04-14				85	4.8	408							88	5.0	440						
				30	2.1	63							92	3.9	358.8						
													72	2.0	144						
													30	0.6	18						
													86	0.5	43						
													68	3.8	258.4						
													68	1.0	68						
													74	4.6	340.4						
Totals		82.1	5977.8		220.9	17103.7		303.4	25463.1		36.8	3385.5		240.7	12478.5		60.8	362.7		7.1	707.2
Weighted RQD's			72.81			77.43			83.93			92.00			51.84			5.97			99.61

	Limestone Unit Weight (pcf)	Upper Sandstone Unit Weight (pcf)	Sandy Siltstone Unit Weight (pcf)	Silstone Unit Weight (pcf)	Shale Unit Weight (pcf)
SAMPLE 1	170.1	154.2	165.1	162.1	161.3
SAMPLE 2	168.0	156.3	172.1	167.6	162.1
SAMPLE 3	168.8	145.8	143.8	167.4	161.4
SAMPLE 4	168.6	140.8	155.9	164.7	161.3
SAMPLE 5	167.3	143.2	161.6	167.3	
Average Unit Weight=	168.56	148.06	159.70	165.82	161.53

EXHIBIT II-7

UPLIFT

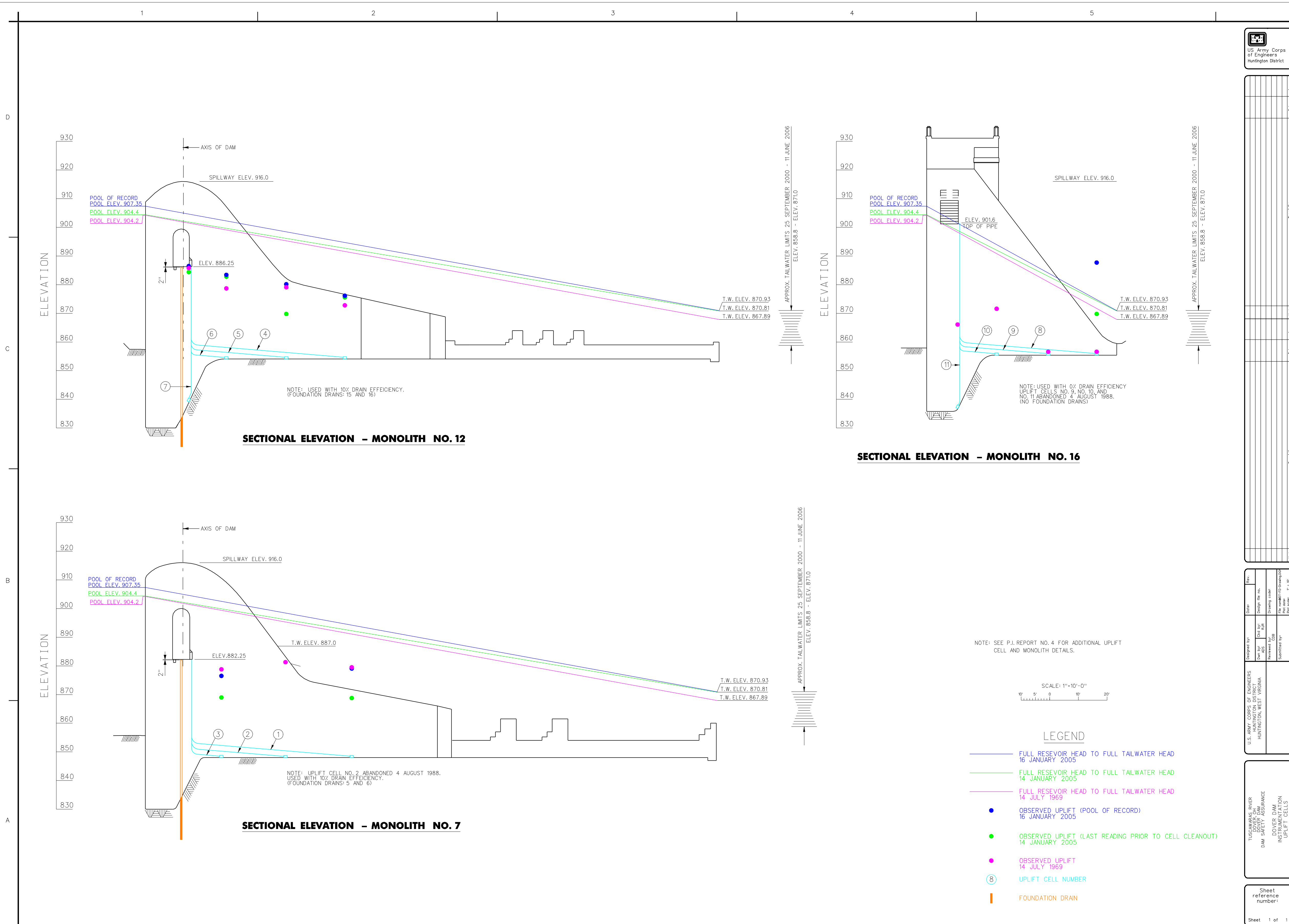
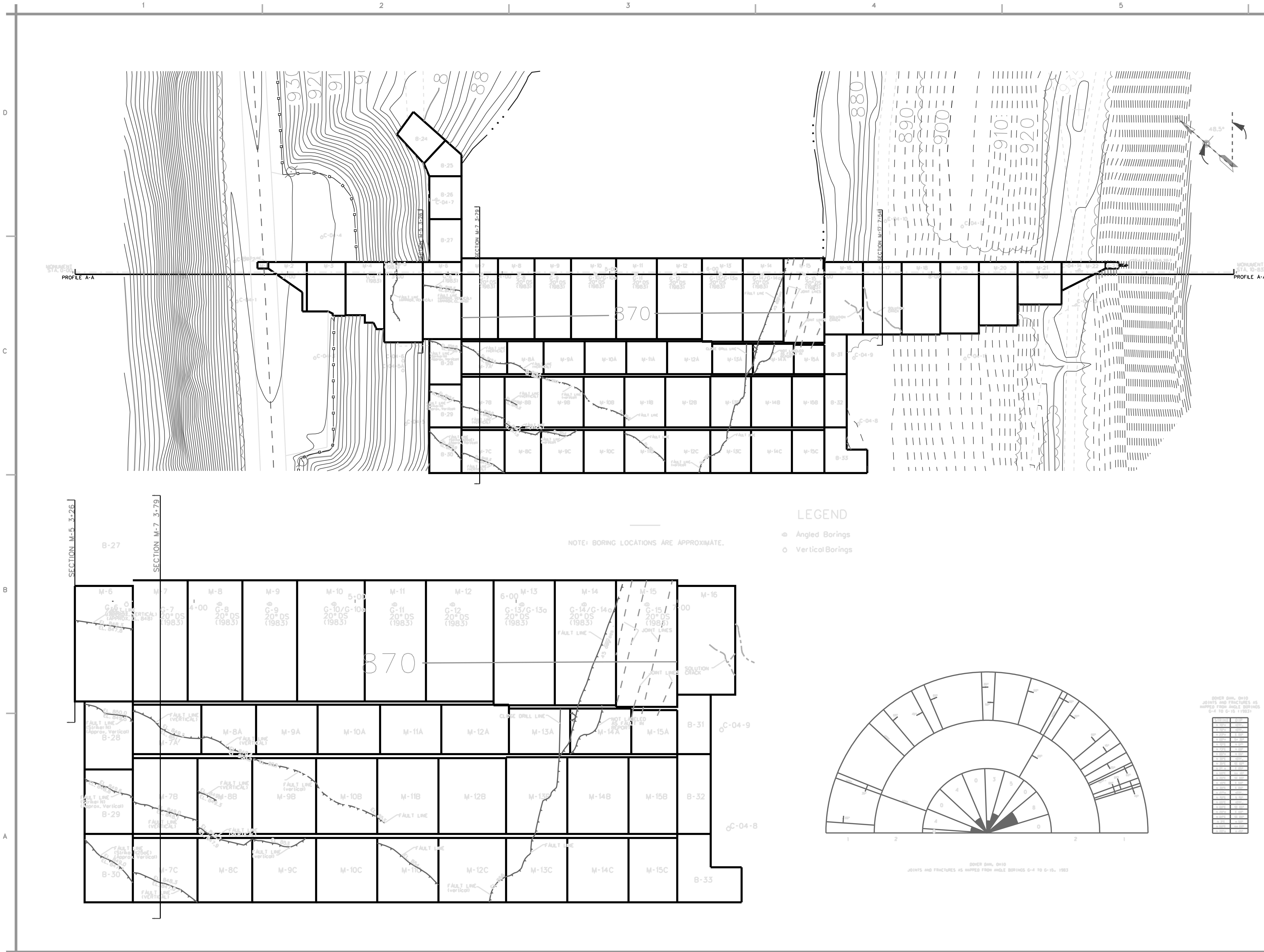

US Army Corps of Engineers
Huntington District
SECTIONAL ELEVATION – MONOLITH NO. 12
SECTIONAL ELEVATION – MONOLITH NO. 16
SECTIONAL ELEVATION – MONOLITH NO. 7
ELEVATION
AXIS OF DAM
SPILLWAY ELEV. 916.0
POOL OF RECORD
POOL ELEV. 907.35
POOL ELEV. 904.4
POOL ELEV. 904.2
ELEV. 886.25
ELEV. 882.25
ELEV. 901.6
TOP OF PIPE
T.W. ELEV. 887.0
T.W. ELEV. 870.93
T.W. ELEV. 870.81
T.W. ELEV. 867.89
APPROX. TALWATER LIMITS 25 SEPTEMBER 2000 - 11 JUNE 2006
ELEV. 858.8 - ELEV. 871.0
NOTE: USED WITH 10% DRAIN EFFECIENCY.
(FOUNDATION DRAINS 15 AND 16)
NOTE: USED WITH 0% DRAIN EFFICIENCY
UPLIFT CELLS NO. 9, NO. 10, AND
NO. 11 ABANDONED 4 AUGUST 1988.
(NO FOUNDATION DRAINS)
NOTE: UPLIFT CELL NO. 2 ABANDONED 4 AUGUST 1988.
USED WITH 10% DRAIN EFFECIENCY.
(FOUNDATION DRAINS 5 AND 6)
NOTE: SEE P.I. REPORT NO. 4 FOR ADDITIONAL UPLIFT
CELL AND MONOLITH DETAILS.
SCALE: 1"=10'-0"
LEGEND
FULL RESEVOIR HEAD TO FULL TAILWATER HEAD
16 JANUARY 2005
FULL RESEVOIR HEAD TO FULL TAILWATER HEAD
14 JANUARY 2005
FULL RESEVOIR HEAD TO FULL TAILWATER HEAD
14 JULY 1969
OBSERVED UPLIFT (POOL OF RECORD)
16 JANUARY 2005
OBSERVED UPLIFT (LAST READING PRIOR TO CELL CLEANOUT)
14 JANUARY 2005
OBSERVED UPLIFT
14 JULY 1969
UPLIFT CELL NUMBER
FOUNDATION DRAIN
U.S. ARMY CORPS OF ENGINEERS
HUNTINGTON DISTRICT
HUNTINGTON, WEST VIRGINIA
TUSCARAWAS RIVER
DOVER DAM
DAM SAFETY ASSURANCE
DOVER DAM
INSTRUMENTATION
UPLIFT CELLS
Sheet reference number:
Sheet 1 of 1

EXHIBIT II-7

EXHIBIT II-8

MAPPING OF FAULTS AND JOINTS



US Army Corps of Engineers
Huntington District

TUSCARAWAS RIVER
DOVER DAM
DAM SAFETY ASSURANCE

Sheet reference number:
EXH 8
Sheet 1 of 1

EXHIBIT II-9

ANCHOR EMBEDMENT

DOVER DSA MON 7 45 degree Anchors

Summary of Anchor Calculations

	Anchor depth (feet)	**46**				
	Bond length (feet)	**45**				
			Design 60%	**Max Test 80%**	**Lock Off 70%**	**GUTS**
.06 inch strand, with design load 35.2 kips		# of strands	Load kips	Load kips	Load kips	kips
	Per strand	1	35.2	46.8	41.0	58.6
	Per anchor	61	2144.76	2853	2502	
	Anchors Per area	3	6434.28			

ANALYSIS FOR TENSION ANCHOR SYSTEMS : ANCHOR DEPTHS (EM 1110-1-2908)

Description	***Symbol***	***Value***	
pcf effective unit weight of rock		160	
FS = factor of safety	FS=	4	
c = rock mass cohesion intercept*	c=	4355.1	psf
F = anchor force required for stability	F=	2144760	pounds
w = unit weight of rock	w=	97.6	pcf Buoyant Weight
s = anchor spacing	s=	22	ft
l = row spacing (for anchors with multiple rows)	l=	8	ft

Application	***Formula***	***Results***
single anchors in competent rock	sqrt(FS*F/c*3.14159)	25
single row of anchors in competent rock	(FS*F)/cs	90
multiple row of anchors in competent rock, with a factor of safety of 1.5	(FS*F)/wls	187
single anchor in fractured rock, with a factor of safety of 1.5	cbrt((3FS*F)/(w*3.14159))	32
single row of anchors in fractured rock, with a factor of safety of 1.5	sqrt(FS*F/ws)	39
multiple row of anchors in fractured rock, with a factor of safety of 1.5	(FS*F)/wls	187

* c= a weighted average of the cross bed shear strength

single anchor in fractured rock with the combined force of all the anchors in that monolith	cbrt((3FS*F)/(w*3.14159))	45.5

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)		SHEAR STRENGTH (psi)	
limestone	4.00		150	(test)
Upper Sandstone	0.00		88	(test)
Siltstone / Sandy	25.00		20	(test)
Siltstone	8.00		15	(test)
Shale	4.00		5	(test)
TOTAL THICKNESS BENEATH FAILURE	41.00	feet		
	WEIGHTED MEAN:		30	psi
			rock mass cohesion*	

* c= a weighted average of the cross bed shear strength

CALCULATING BOND LENGTHS FOR ROCK ANCHOR SYSTEM

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)		BOND STRENGTH (psi)	
Limestone	0.00		85	(test)
Sandstone	0.00		110	(test)
Siltstone / Sandy	45.00		95	(test)
Siltstone	0.00		90	(test)
Shale	0.00		50	(test)
TOTAL THICKNESS OF BOND ZONE:	45.00	feet		
	WEIGHTED MEAN:		95	psi
			Working Bond Strength	

COMPARISONS - VARYING HOLE DIAMETERS:

COMPOSITE LITHOLOGY using working bond strength, and various diameters				
LOCK OFF KIPS:	2502	2502	2502	2502
ANCHOR BOND STRENGTH (CHOSEN):	95	95	95	95
HOLE DIAMETER (in.):	14.00	15.00	16.00	16.25
RADIUS	7.00	7.50	8.00	8.13
BOND AREA REQ'D. (sq. in.):	26339.16	26339.16	26339.16	26339.16
ANCHOR BOND LENGTH (in.):	599	559	524	516
ANCHOR BOND LENGTH (ft.):	49.9	46.6	43.7	43.0
			45	

THE GRAY HIGHLIGHTED BOND LENGTH REPRESENTS THE LENGTH CHOSEN FOR THIS ANCHOR BASED ON THE DIAMETER OF THE HOLE

DOVER DSA MON 7A Vertical Anchors

Summary of Anchor Calculations

Anchor depth (feet)	**27**
Bond length (feet)	**25**

		Design 60% Load kips	**Max Test 80%** Load kips	**Lock Off 70%** Load kips	**GUTS** kips
Area of Bar	**3.14**				
Bar Size in Inches	2	283	376	330	471
Bar strength ksi	**150**				
Anchors Per area	4	1131			

ANALYSIS FOR TENSION ANCHOR SYSTEMS : ANCHOR DEPTHS (EM 1110-1-2908)

Description	***Symbol***	***Value***
pcf effective unit weight of rock		160
FS = factor of safety	FS=	4
c = rock mass cohesion intercept*	c=	4355.1 psf
F = anchor force required for stability	F=	282743 pounds
w = unit weight of rock	w=	97.6 pcf Buoyant Weight
s = anchor spacing	s=	15 ft
l = row spacing (for anchors with multiple rows)	l=	15 ft

Application	***Formula***	***Results***
single anchors in competent rock	sqrt(FS*F/c*3.14159)	9
single row of anchors in competent rock	(FS*F)/cs	17
multiple row of anchors in competent rock, with a factor of safety of 1.5	(FS*F)/wls	19
single anchor in fractured rock, with a factor of safety of 1.5	cbrt((3FS*F)/(w*3.14159))	16
single row of anchors in fractured rock, with a factor of safety of 1.5	sqrt(FS*F/ws)	17
multiple row of anchors in fractured rock, with a factor of safety of 1.5	(FS*F)/wls	19

* c= a weighted average of the cross bed shear strength

single anchor in fractured rock with the combined force of all the anchors in that monolith	cbrt((3FS*F)/(w*3.14159))	25.5

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	SHEAR STRENGTH (psi)	
limestone	4.00	150	(test)
Upper Sandstone	0.00	88	(test)
Siltstone / Sandy	25.00	20	(test)
Siltstone	8.00	15	(test)
Shale	4.00	5	(test)
TOTAL THICKNESS BENEATH FAILURE	41.00 feet		
	WEIGHTED MEAN:	30	psi
		rock mass cohesion*	

* c= a weighted average of the cross bed shear strength

CALCULATING BOND LENGTHS FOR ROCK ANCHOR SYSTEM

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	BOND STRENGTH (psi)	
Limestone	0.00	85	(test)
Sandstone	0.00	110	(test)
Siltstone / Sandy	25.00	95	(test)
Siltstone	0.00	90	(test)
Shale	5.00	50	(test)
TOTAL THICKNESS OF BOND ZONE:	30.00 feet		
	WEIGHTED MEAN:	88	psi
		Working Bond Strength	

COMPARISONS - VARYING HOLE DIAMETERS:

COMPOSITE LITHOLOGY using working bond strength, and various diameters

LOCK OFF KIPS:	330	330	330	330
ANCHOR BOND STRENGTH (CHOSEN):	88	88	88	88
HOLE DIAMETER (in.):	3.00	4.00	5.00	6.00
RADIUS	1.50	2.00	2.50	3.00
BOND AREA REQ'D. (sq. in.):	3769.91	3769.91	3769.91	3769.91
ANCHOR BOND LENGTH (in.):	399	300	240	200
ANCHOR BOND LENGTH (ft.):	33.3	25.0	20.0	16.6
			25	

THE GRAY HIGHLIGHTED BOND LENGTH REPRESENTS THE LENGTH CHOSEN FOR THIS ANCHOR BASED ON THE DIAMETER OF THE HOLE

DOVER DSA MON 7B Vertical Anchors

Summary of Anchor Calculations

Anchor depth (feet)	**31**				
Bond length (feet)	**25**				
		Design 60% Load kips	**Max Test 80%** Load kips	**Lock Off 70%** Load kips	**GUTS** kips
Area of Bar	**3.14**				
Bar Size in Inches	2	283	376	330	471
Bar strength ksi	**150**				
Anchors Per area	6	1696			

ANALYSIS FOR TENSION ANCHOR SYSTEMS : ANCHOR DEPTHS (EM 1110-1-2908)

Description	*Symbol*	*Value*
pcf effective unit weight of rock		160
FS = factor of safety	FS=	4
c = rock mass cohesion intercept*	c=	4355.1 psf
F = anchor force required for stability	F=	282743 pounds
w = unit weight of rock	w=	97.6 pcf Buoyant Weight
s = anchor spacing	s=	15 ft
l = row spacing (for anchors with multiple rows)	l=	15 ft

Application	*Formula*	*Results*
single anchors in competent rock	sqrt(FS*F/c*3.14159)	9
single row of anchors in competent rock	(FS*F)/cs	17
multiple row of anchors in competent rock, with a factor of safety of 1.5	(FS*F)/wls	19
single anchor in fractured rock, with a factor of safety of 1.5	cbrt((3FS*F)/(w*3.14159))	16
single row of anchors in fractured rock, with a factor of safety of 1.5	sqrt(FS*F/ws)	17
multiple row of anchors in fractured rock, with a factor of safety of 1.5	(FS*F)/wls	19

* c= a weighted average of the cross bed shear strength

single anchor in fractured rock with the combined force of all the anchors in that monolith	cbrt((3FS*F)/(w*3.14159))	29.2

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	SHEAR STRENGTH (psi)	
limestone	4.00	150	(test)
Upper Sandstone	0.00	88	(test)
Siltstone / Sandy	25.00	20	(test)
Siltstone	8.00	15	(test)
Shale	4.00	5	(test)
TOTAL THICKNESS BENEATH FAILURE	41.00 feet		
	WEIGHTED MEAN:	30	psi
		rock mass cohesion*	

* c= a weighted average of the cross bed shear strength

CALCULATING BOND LENGTHS FOR ROCK ANCHOR SYSTEM

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	BOND STRENGTH (psi)	
Limestone	0.00	85	(test)
Sandstone	0.00	110	(test)
Siltstone / Sandy	25.00	95	(test)
Siltstone	0.00	90	(test)
Shale	5.00	50	(test)
TOTAL THICKNESS OF BOND ZONE:	30.00 feet		
	WEIGHTED MEAN:	88	psi
		Working Bond Strength	

COMPARISONS - VARYING HOLE DIAMETERS:

COMPOSITE LITHOLOGY using working bond strength, and various diameters

LOCK OFF KIPS:	330	330	330	330
ANCHOR BOND STRENGTH (CHOSEN):	88	88	88	88
HOLE DIAMETER (in.):	3.00	4.00	5.00	6.00
RADIUS	1.50	2.00	2.50	3.00
BOND AREA REQ'D. (sq. in.):	3769.91	3769.91	3769.91	3769.91
ANCHOR BOND LENGTH (in.):	399	300	240	200
ANCHOR BOND LENGTH (ft.):	33.3	25.0	20.0	16.6
			25	

THE GRAY HIGHLIGHTED BOND LENGTH REPRESENTS THE LENGTH CHOSEN FOR THIS ANCHOR BASED ON THE DIAMETER OF THE HOLE

DOVER DSA MON 7C Vertical Anchors

Summary of Anchor Calculations

Anchor depth (feet)	27					
Bond length (feet)	25					
			Design 60%	Max Test 80%	Lock Off 70%	GUTS
Area of Bar	3.14		Load kips	Load kips	Load kips	kips
Bar Size in Inches	2		283	376	330	471
Bar strength ksi	150					
Anchors Per area	4		1131			

ANALYSIS FOR TENSION ANCHOR SYSTEMS : ANCHOR DEPTHS (EM 1110-1-2908)

Description	*Symbol*	*Value*
pcf effective unit weight of rock		160
FS = factor of safety	FS=	4
c = rock mass cohesion intercept*	c=	4355.1 psf
F = anchor force required for stability	F=	282743 pounds
w = unit weight of rock	w=	97.6 pcf Buoyant Weight
s = anchor spacing	s=	15 ft
l = row spacing (for anchors with multiple rows)	l=	15 ft

Application	*Formula*	*Results*
single anchors in competent rock	sqrt(FS*F/c*3.14159)	9
single row of anchors in competent rock	(FS*F)/cs	17
multiple row of anchors in competent rock, with a factor of safety of 1.5	(FS*F)/wls	19
single anchor in fractured rock, with a factor of safety of 1.5	cbrt((3FS*F)/(w*3.14159))	16
single row of anchors in fractured rock, with a factor of safety of 1.5	sqrt(FS*F/ws)	17
multiple row of anchors in fractured rock, with a factor of safety of 1.5	(FS*F)/wls	19

* c= a weighted average of the cross bed shear strength

single anchor in fractured rock with the combined force of all the anchors in that monolith	cbrt((3FS*F)/(w*3.14159))	25.5

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	SHEAR STRENGTH (psi)	
limestone	4.00	150	(test)
Upper Sandstone	0.00	88	(test)
Siltstone / Sandy	25.00	20	(test)
Siltstone	8.00	15	(test)
Shale	4.00	5	(test)
TOTAL THICKNESS BENEATH FAILURE	41.00 feet		
	WEIGHTED MEAN:	30	psi
		rock mass cohesion*	

* c= a weighted average of the cross bed shear strength

CALCULATING BOND LENGTHS FOR ROCK ANCHOR SYSTEM

ROCK TYPES PRESENT	AVG. THICKNESS (ft.)	BOND STRENGTH (psi)	
Limestone	0.00	85	(test)
Sandstone	0.00	110	(test)
Siltstone / Sandy	25.00	95	(test)
Siltstone	0.00	90	(test)
Shale	5.00	50	(test)
TOTAL THICKNESS OF BOND ZONE:	30.00 feet		
	WEIGHTED MEAN:	88	psi
		Working Bond Strength	

COMPARISONS - VARYING HOLE DIAMETERS:

COMPOSITE LITHOLOGY using working bond strength, and various diameters				
LOCK OFF KIPS:	330	330	330	330
ANCHOR BOND STRENGTH (CHOSEN):	88	88	88	88
HOLE DIAMETER (in.):	3.00	4.00	5.00	6.00
RADIUS	1.50	2.00	2.50	3.00
BOND AREA REQ'D. (sq. in.):	3769.91	3769.91	3769.91	3769.91
ANCHOR BOND LENGTH (in.):	399	300	240	200
ANCHOR BOND LENGTH (ft.):	33.3	25.0	20.0	16.6
			25	

THE GRAY HIGHLIGHTED BOND LENGTH REPRESENTS THE LENGTH CHOSEN FOR THIS ANCHOR BASED ON THE DIAMETER OF THE HOLE